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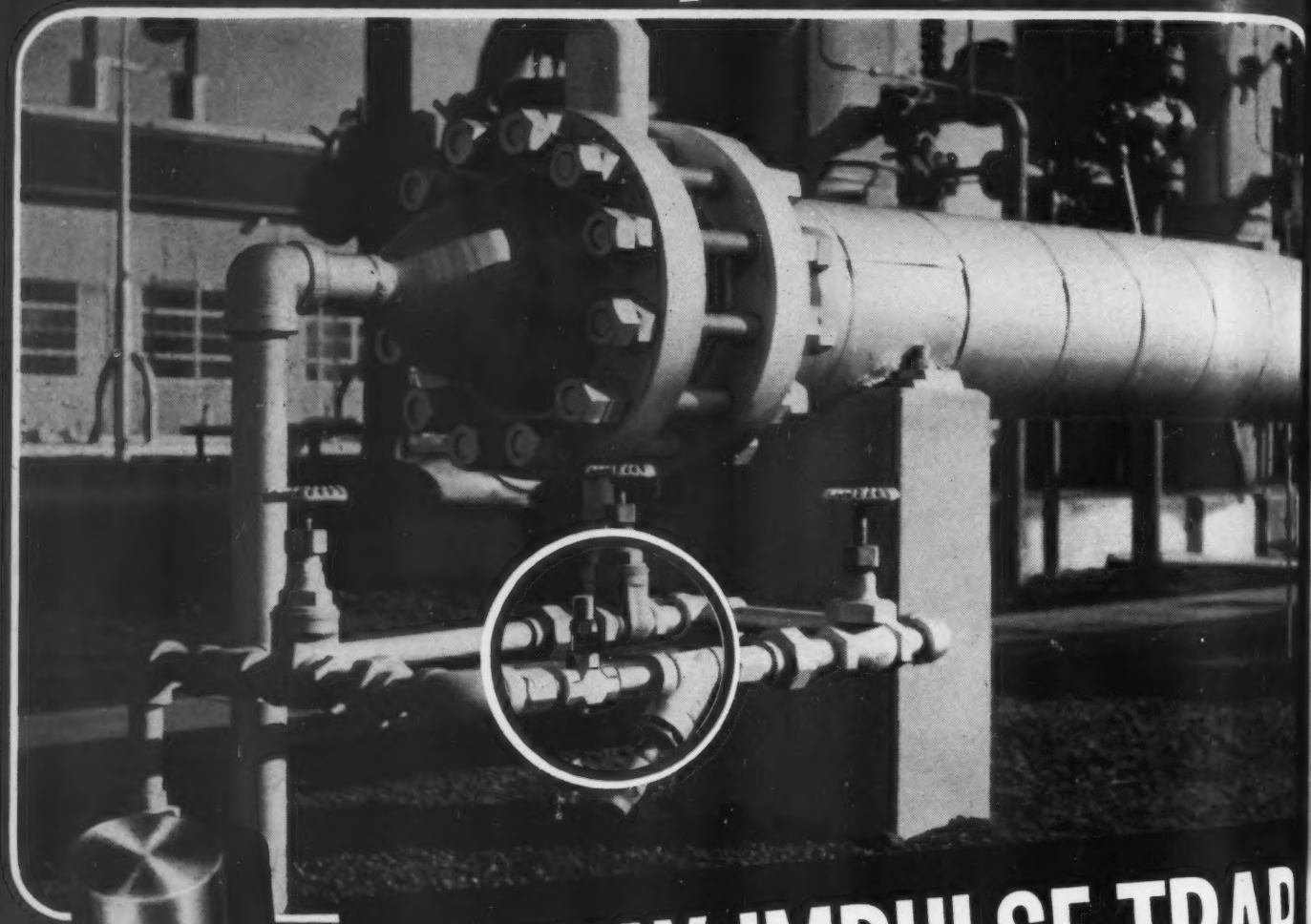

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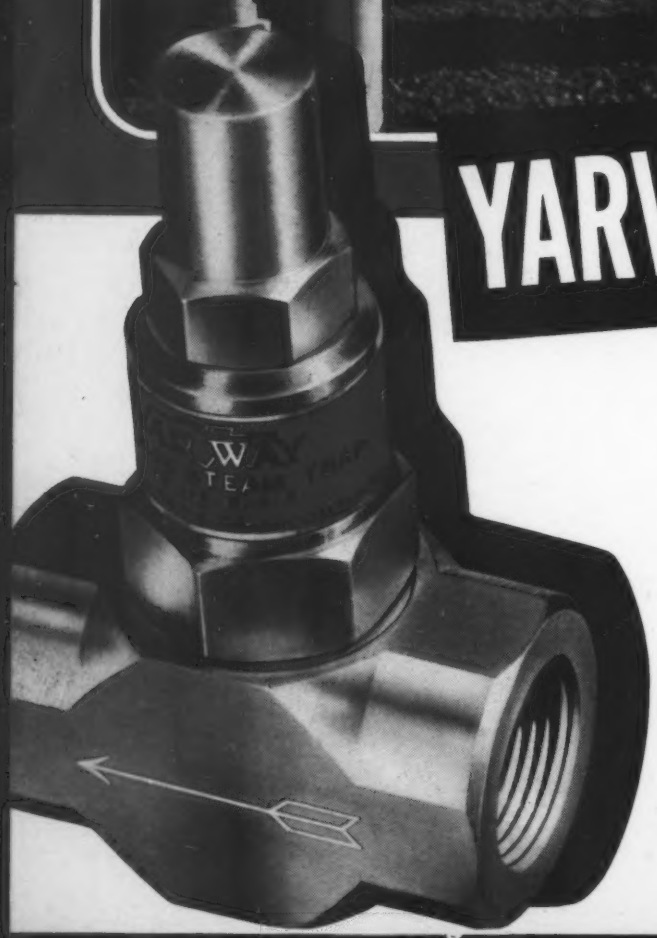

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PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

October, 1943
Vol. 22, No. 10

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GRADY TRIPLETT
Editor

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This is a

WAR OF CHEMICALS, TOO

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VOLUME 22, NO. 10 OCTOBER, 1943

PETROLEUM
REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

A GULF PUBLISHING COMPANY PUBLICATION

THE LOOK BOX

EVIDENTLY synthetic rubber is coming from the new plants in quantity greater than expected at this date. At least executives of the rubber industry indicate that in recent statements. If so the development brought one crisis to an end.

From Crisis To Crisis

The accomplishment at the same time brought another crisis into existence. Now there are not enough workmen at hand to process the rubber into finished products, especially casings and tires.

The plea still stands that each automobile owner look upon his tires as precious products of elasticity. There may be more synthetic rubber than the season anticipated but there will not be as much automotive rubber as the nation could use.

EVIDENCE that authority to control does not assure an ample petroleum supply is to be had from reading statistics of the industry. Its storage tanks are scarcely converted in some instances. Stocks are diminishing against rising needs.

Without Guarantee

This condition continues despite the fact that the petroleum industry has as competent control as the federal government can boast. Since the Office of Petroleum Coordinator was established, Harold L. Ickes has found little opposition either from government or from the industry. His recommendations of crude-oil production have been accepted as directives by the state conservation agencies. Refinery throughput has followed other recommendations of his office. Additional refining facilities have been built as his calculations recommended.

Despite all this, there is a diminishing supply of finished petroleum products. If this diminishing supply were the result of insufficient crude oil and not enough refining capacity, the situation could be dismissed with regret. But this is not true. The oil fields of the United States have not produced all the oil that could have been recovered without physical waste. Neither have its refining plants been operated at capacity.

In large measure the daily totals of crude-oil production and the daily throughput of refining plants have represented what men in Washington considered sufficient.

It was May of this year before refining plants along the Gulf Coast had the privilege of unlimited runs. Even then they were cautioned not to interfere with orders of proration in seeking additional crude oil. Until output of oil fields could be increased, the privilege of refining more crude-oil amounted to a set of words. Especially in Texas the oil fields could have been producing as much oil in October, 1942, as they are in October, 1943. In other areas proration regulations held well output down when it should have been up.

Had there been wisdom equal to the need, the oil fields of the Southwest would have been under no restraint or less restraint a year ago and the smaller refining plants along the Texas Gulf Coast

would not have been restricted to 70 percent of their throughput prior to May, 1943.

Control cannot be expected to supply what does not exist. The expectation is that the full use of supply be provided. In oil at least the full use of supply has not been provided and the control of oil will match any other control in Washington.

One criticism does apply to administration in PAW. Of late it has devoted much attention to crude-oil reserves. High concern attaches to the amount of crude-oil this nation may have a dozen or a score of years from now.

It is far better that its oil fields produce to their limit today than that there be ample supply for a next generation. Unless there is sufficient oil for a gigantic war machine, the next generation will be concerned with only a few simple products, food, clothing and shelter.

The Shift To Oil

IN 1918, most active industrial year of World War I, energy from mineral source was divided as follows: coal 85 percent, oil 12 percent, gas 3 percent. In 1941 this relationship had changed to leave coal with 57 percent, oil 32 percent and natural gas 11 percent.

In a quarter of a century oil and natural gas had risen from a place of providing one seventh of the mineral energy of the United States almost to the half way mark. In large measure the rise was due to the development of the cheap automobile.

Over that period the consumption of coal dropped. Now, however, the inability to provide oil for all purposes over the nation has given coal an opportunity to regain part of its lost domain as an energy source.

Chemicals From Oil

MOST of the utilization of petroleum hydrocarbons for chemical manufacture has been based on the use of olefins made by cracking. Although the amounts of ethylene, propylene, and butenes made by pressure-cracking processes have been large in the aggregate, their concentration in by-product gases has generally been so low that in many cases it has been more advantageous to operate special cracking processes, using propane, butane, or other oils, to get gases rich in these olefins. The use of higher cracking temperatures to obtain gasoline of higher octane numbers and catalytic cracking under certain conditions to obtain butene and butadiene, has greatly increased the output of ethylene and propylene and in many cases yields these in relatively high concentration. War censorship advisedly prevents details of these operations. The list of important chemicals now being manufactured from ethylene and propylene is fairly well known and includes ethyl alcohol, ethyl chloride for the manufacture of tetraethyl lead, ethylene dichloride, vinyl chloride for vinyl plastics, ethylene glycol, ethylene oxide, and a series of derived products, isopropyl alcohol, acetone, acetic anhydride, butyl alcohols, methyl ethyl ketone, amyl alcohols, butyl rubber from isobutene (and butadiene or isoprene), viscous and solid polymers from isobutene, alkyl amines, nitroparaffins, and a larger number of other products of lesser importance.

"The most important synthetic product now made by the petroleum industry is butadiene for synthetic Buna S and Buna N rubbers. The manufacture of butadiene and 100-octane aviation gasoline is more or less interrelated. Both processes seem certain to survive on a large scale, though perhaps not on the present scale, after the war. Quantitatively, against the statistical background of the petroleum industry, butadiene and synthetic rubber are not important. Their cost after the war will depend to a considerable extent upon the demand for and value of 100-octane gasoline since the raw materials for both are interrelated. Butadiene made only from the butene-by-product of catalytic cracking and from heretofore normally surplus butane could remain at a relatively low cost figure largely independent of the price structure of crude and ordinary motor fuel."

—Extract from an article by Benjamin T. Brooks in Chemical and Engineering News.

Shorter Routes

SELECTION of direct conversion of butane into butadiene, the first study of the new laboratory of the Bureau of Mines at Bartlesville, is an indication that the cost of synthetic rubbers will steadily decrease. Fortunately many other laboratories are also studying this problem.

Butadiene represents 75 percent of Buna S rubber. If one step of dehydrogenation of butane can make it rather than the two steps now used, the cost will move downward.

So many technologists are working on cost-reduction programs for synthetic-rubber ingredients that success must be accepted. When and how much are not predictable. Technologists have reduced costs of so many products that rubber can not escape.

This research is the basis for the predictions that in time synthetic rubber will be not only superior to natural rubber but cheaper.

Refining of West Texas Crude

B. I. SCOGGIN, Manager of Research and Development
G. H. BURRUSS, Manager of Refineries, Anderson-Prichard Oil Corporation

This paper was presented before a technical meeting of the Western Petroleum Refiners Association, Tulsa, October 12

THE purpose of this paper is to discuss the refining of West Texas crude oil from the viewpoint of a Mid-Continent refiner who may soon be forced to seek a supplementary crude source.

We refer to Mid-Continent refiners in this paper with particular emphasis on refiners in Oklahoma and Kansas. No doubt each refiner who considers processing West Texas crude oil will be faced with many problems that will force him to alter his refining methods. This change in refining methods due to change in raw materials is obvious. It is just as important that forced changes in management and sales policies be recognized from the start. This will be of material aid to the refiner by elimination of misunderstanding due to changes in old products. Likewise, those in charge of sales policies will welcome an opportunity to gain early information regarding new products.

Crude Analysis and Planning Operations

From this point on we will endeavor to cover facts in the order that they will probably be covered by any refiner who eventually changes a part of his operation from Mid-Continent crude to West Texas crude.

We have no processes for sale and no editorial policy to follow; therefore, we hope to use the minimum number of names of patented processes. Generally speaking, West Texas crude has been and can be completely and successfully processed without any of the licensed processes. Regardless of this fact, however, it may well be to the refiner's advantage to use a patented process and pay the necessary royalty since the people who have developed and are promoting such processes are usually well acquainted with characteristics of West Texas crude oil and can give excellent technical service which will be difficult for every refiner to develop within his own organization under present manpower conditions.

The term "West Texas crude" now has so many different meanings that it requires additional explanation. Table 1 will serve to illustrate this point. From this chart it will be noted that there is considerable variation in the crude oils produced in the various areas in Texas with possible variations in octane number of from 20 to 65 in the ASTM octane number of 400-end-point gasoline. Several people who have examined this table have asked for information concerning the sulfur content of each crude. Sulfur content could have been furnished, but we elected not to furnish this information since our experience has shown that such information is often more academic than practical and may even be misleading. Also, there are a number of publications available that will give information concerning total sulfur content, one of the best being the United States Bureau of Mines, R.I. 3699, April, 1943. There are several other similar listings in current literature.[1]

One of the surprising facts about West Texas production is that we could go down the list as shown in Table 1 and write in sulfur contents from .1 of 1 percent to 3 percent at will and later be able to prove that these sulfur contents were correct. The important fact about sulfur content of West Texas crude is that it is available not only from field to field but within each field. Most West Texas fields produce from zones rather than from one major sand. The producing zones are made up of many sands of an apparent lenticular character. No two wells may produce from exactly the same horizons in the same proportions. Sometimes offset wells may vary 100 percent in sulfur content. Therefore, if you are considering the use of West Texas crude in your Mid-Continent refinery, it is necessary that you maintain continuous records, first, of crude-oil analysis and, second, of the materials produced from a given refining operation. In our own refining operations we have made a practice of making crude-oil analysis upon the average crude from a given area as represented by pipe-line movements, then maintain daily routine checks of the sulfur content of the gasoline streams. Any noticeable variation in the sulfur content of the gasoline produced can then be recorded and eventually correlated with analysis of the crude oil from sample obtained near its source. Over a period of time this will prove to be very useful information.

Figure 1 shows a form of graphical presentation of crude-oil analysis that has been found useful in planning operations of West Texas crude oil. All petroleum refiners are acquainted with crude-oil breakdowns into percentages of various salable products. The usual refiner is mostly interested in the percent yield of gasoline as compared to the end point of the gasoline produced. In examination of the crude of high sulfur content, you must consider an additional factor in calculating yield of gasoline. This factor is sulfur content of the gasoline. Examination of the curve for the sulfur content versus the curve for octane number in Figure 1 shows the definite relationship between these two properties. Often it will be more practicable to operate from the standpoint of a given yield of a certain sulfur-content product than to operate with a given yield of a certain end-point product. This is an important item in your considerations of West Texas crude. Under your present operations the sulfur determination

apparatus that you have in your laboratory may be of minor consideration. As one refiner said, "Just an important looking piece of apparatus to show visitors in the plant." For a successful operation with West Texas crude oil, sulfur determinations become routine operational duties, equally as important as any other form of data used in plant-control operations.

Incidentally, from a practical standpoint, we have in recent years found very little practical use of total sulfur content of a crude oil. First, the testing procedure is a long one of questionable accuracy when performed by routine testers; second, the sulfur content of the gasoline stream can be safely used in calculating sulfur content of other products, that is, insofar as refining operations are concerned. The lamp method of determining total sulfur content of gasoline is a more rapid and dependable test procedure. Note Table 2 is a breakdown of West Texas crude oil into various types of products. Note that the crude oil had a total sulfur content of 2.86 and that evidently this sulfur content is distributed through the various products in proportion to the molecular weight and boiling point, the low-end-point gasoline having the lowest sulfur content and fuel-oil asphalt having sulphur content of above 4 percent.[21]

Until recently there were a number of federal government and state specifications requiring that motor gasoline have not more than .1 of 1 percent sulfur. However, there has been an enlightened viewpoint on this subject and the federal government has changed specifications to allow up to .25 of 1 percent sulfur in gasoline used by the federal government. If you have not thoroughly investigated the facts concerning sulfur content of gasoline, you may believe that there was at one time some logical justification for the limit of sulfur content. Actually there has never been a logical justification for such laws and the former federal laws were apparently arrived at, more or less, by accident at a time when all of the available gasoline contained not more than .1 of 1 percent sulfur.[2]

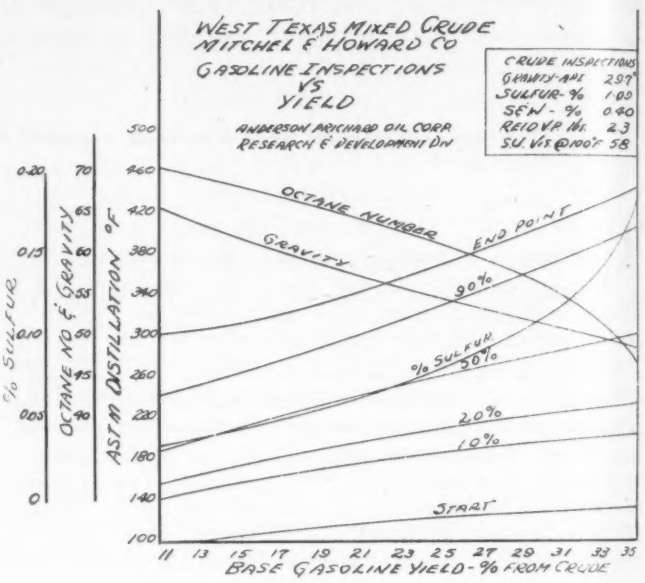

FIGURE 1

It is finally realized that any motor that is actually harmed by high-sulfur motor fuel will also be harmed to an almost equal extent by the use of any other type motor fuel. One of the classical examples of this behavior was brought out a number of years ago when the manufacturer of certain types of automobiles advised a manufacturer of a high-sulfur benzol that if the sulfur content was not lowered he would be forced to advise the distributors of his automobiles and their customers not to use his benzol. The benzol manufacturer investigated the problem and after due consideration advised the automobile man to "Go as far as you like, but at the same time we will be forced to advertise something else that may be news to you. Yours is the only one of many makes of automobiles in which this benzol has been used in which it has caused corrosion.[3] A subsequent investigation of this problem yielded the feature known as crankcase ventilation.[4] Without such ventilation, extremely corrosive compounds will form from carbon dioxide and water plus presence of chlorine and bromine that are a part of tetraethyl lead compounds. Actually, straight-run gasoline from West Texas crude oils is a better grade of motor fuel than the straight-run gasoline manufactured from Mid-Continent crude oil. The question of sulfur content is interesting and important from the standpoint of process control and equipment protection, but of no practical significance from the standpoint of motor-fuel use.

Further examination of Table 2 yields other information which should be emphasized. Note that the

TABLE 1

Analysis of West Texas Crude Oils

(From Railroad Commission of Texas, Analyses of Texas Crude Oils, October 25, 1940.)

FIELD	COUNTY	Crude °API	400° F. End Point Gasoline		
			Per Cent	°API	Octane ASTM
Apco	Pecos	40.1	29.2	63.4	22
Cedar Lake	Gaines	35.5	32.0	56.7	54
Cowden N.	Ector	32.9	31.3	57.5	53
Cowden No. Deep	Ector	31.3	21.2	50.6	42
Cowden So.	Ector	34.7	32.3	56.7	53
Crane Cowden	Crane	29.5	23.7	55.6	51
Duggan	Cochran	28.7	30.3	52.3	55
Dune	Crane	32.0	26.8	56.6	52
Emma	Andrews	33.4	32.6	56.8	55
Emperor	Winkler	32.6	29.6	55.7	54
Emperor Deep 2	Winkler	31.7	28.2	54.4	52
Estes Pool	Ward	34.4	33.3	58.4	54
Foster	Ector	35.9	33.3	58.1	52
Fuhrman	Andrews	23.9	16.7	51.5	53
Gulf McElroy	Crane & Upton	30.9	25.3	56.4	50
Halley	Winkler	31.7	27.2	57.1	56
Harper	Ector	34.8	33.3	55.6	48
Henderson	Winkler	28.5	18.8	55.4	57
Hendrick	Winkler	24.4	11.4	48.0	58
Iatan East Howard	Howard & Mitchell	30.0	29.6	53.4	58
Howard Glasscock E	Howard & Glasscock	33.2	18.7	55.2	58
Johnson	Ector	35.2	32.4	57.2	51
Jordan	Crane	32.8	30.8	55.2	50
Kermit	Winkler	34.6	32.6	56.0	50
Keystone (Colby)	Winkler	37.9	34.1	58.8	47
Leck	Winkler	28.1	21.1	54.2	58
Lehn	Pecos	32.2	28.7	54.8	56
Magnolia Sealy	Ward	29.1	25.0	55.6	49
Mason	Loving	40.3	36.0	57.3	50
Masterson	Pecos	30.9	26.0	55.0	48
Means	Andrews	29.6	23.0	56.9	57
Payton	Pecos & Ward	33.5	29.5	55.6	51
Pecos Valley Hi. Gr.	Pecos	38.4	37.3	59.4	52
Pecos Valley Low Gr.	Pecos	22.7	8.4	47.2	65
Penwell	Ector	35.9	33.6	57.4	53
Sand Hills (Permian)	Crane	29.7	30.5	54.8	50
Sand Hills (Ordovician)	Crane	45.3	37.6	65.2	20
Scarborough	Winkler	31.8	22.5	52.9	43
Seminole	Gaines	33.6	33.0	57.3	54
Sharon Ridge	Scurry & Mitchell	29.8	28.6	54.6	57
Shearer	Pecos	33.4	28 3	56.4	50
Shipley	Ward	35.7	33.3	58.4	54
Slaughter	Hockley	31.3	32.2	55.9	56
Snyder	Howard	30.1	30.3	55.1	59
Taylor Link	Pecos	32.1	20.2	53.3	57
Waddell	Crane	33.5	28.6	58.3	51
Ward No.	Ward	30.8	25.6	52.9	52
Ward So.	Ward	31.8	24.8	53.1	46
Wasson	Yokum & Gaines	32.8	31.6	55.9	55
Westbrook	Mitchell	26.1	31.5	51.9	59
Wheat	Loving	38.4	34.1	57.2	53
White & Baker	Pecos	30.6	26.0	55.4	52
Yates	Pecos	29.9	24.0	56.4	60

TABLE 2

Crude Oil Analysis, Westbrook Crude, Mitchell County, Texas

	Crude Charge	GASOLINE STOCKS 350 E.P.	375 E.P.	415 E.P.	435 E.P.	450 E.P.	LIGHT DISTILLATE 35 Gravity	32 Gravity	GAS OIL	FUEL OIL RESIDUUM After 415 E.P.	After 35 Gravity	After 32 Gravity	Asphalt
Percent Yield from Crude				32.00						67.00			
Percent Yield from Crude				32.00			6.10				60.90		
Percent Yield from Crude				32.00				12.20				54.80	
Percent Yield from Crude				32.00				12.20	21.60				33.20
Percent Yield from Crude		22.85	26.90		34.05	35.10	6.10	12.20	21.60	67.00	60.90	54.80	33.20
Gravity	22.5	52.1	50.8	49.2	48.7	48.2	35.1	32.5	24.4	14.3	12.3	11.6	
Flash—C.T.							164	173					
Flash—Clev.									280	260	295	325	
Viscosity at 100° F.	74						33	35	55				
Viscosity at 130° F.										260	540	1140	
Viscosity at 210° F.										69	106	152	
Viscosity Illuminating							490	Too Hvy.					
Pour							—25	—20	60				
Solid							—30	—25					
Color—Saybolt		+25	+25	+23	+21	+16	— 6	B-16					
Doctor Test		Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.					
Strip Copper		Good	Good	Good	Good	Good							
Percent Sulphur	2.86	0.12	0.15	0.20	0.23	0.25	0.89	1.23	2.13	3.45	3.88	4.02	
Percent S & W	0.60												
Percent Mercaptans				0.047									
Octane No.		62.5	59.0	54.5	53.0	52.0							
A.S.T.M. Distillation:										**Asphalt Analysis**			
Start		135	140	144	145	145	436	439	500				
5 Percent		178	183	188	190	191	453	468		Penetration			188
10 Percent		192	200	210	212	215	457	475	574	Melting Point			103
20 Percent		212	222	232	234	237	462	481	590	Ductility			100+
30 Percent		228	238	252	256	258	465	487	602	Flash			495
40 Percent		241	254	270	275	277	469	492	616	Sol. in CS_2			99.9
50 Percent		253	269	288	296	298	473	498	626	Sol. in CCl_4			99.9
60 Percent		264	285	309	320	322	475	505	640	Sol. in 86° Naphtha			88.0
70 Percent		272	295	328	343	349	481	513	655	Fixed Carbon			8.4
80 Percent		288	315	354	374	382	487	525	674	Loss @ 325° F. 5 Hrs.			0.1
90 Percent		308	340	386	408	418	497	543	700	Pen. of Residue			154
95 Percent		328	360	408	434	444	509	560		Shattuck Oxidation Test			Excellent
End Point		350	379	418	440	456	515	569		Benson Film Test			Excellent
Percent Recovered		97.50	98.00	98.00	98.00	98.00	98.00	98.00	90.00	Ductility after 24 Hrs. heat loss			100+
Percent in Flask		1.00	1.00	1.00	1.00	1.00	2.00	2.00	10.00				
Percent Loss		1.50	1.00	1.00	1.00	1.00	0.00	0.00	0.00				
Percent @ 212° F.		20.00	14.50	11.00	10.00	9.00							

light distillate cuts from 32 to 35 gravity have a pour point of minus 20 or below. This is generally true of all such distillates from West Texas crude oils. Furnace distillates and low-pour-point diesel fuel have many characteristics that render them superior to competitive products of the same boiling range from Mid-Continent crude.

Note that an analysis of asphalt products has also been included. You may not be interested in asphaltic materials; however, it is interesting to know that asphalts produced from West Texas crude oil have a very high resistant oxidation and are among the only asphalts produced in the Mid-Continent that will pass the Shattuck oxidation test. Some chemists say this resistance to oxidation is due to the high sulfur content.[5]

Under other phases of this paper we will have occasion to furnish further details concerning the quality of products of West Texas crude. The heavy gasoil cuts usually contain wax, and as you will note from Table 2 have a high cold test. We have no information concerning the possible production of lubeoil or paraffin wax from this type crude. As has been mentioned in several current magazine articles,[6] a satisfactory kerosine cannot be made from West Texas crude by the process used in refining Mid-Continent crude. It is obvious that there may be many other products that could be attractive from a refining and marketing standpoint, but the companies that have been manufacturing a quality grade of range oil, kerosine and the like should not expect to manufacture the same grade of product when operating exclusively on West Texas crude oil. There is a possibility that the government may need considerable quantities of diesel fuel. At present the Army purchases diesel fuel under three types of specifications known as A, B and X.[7] The A and B grades are the type diesel fuel ordinarily manufactured from Mid-Continent crude. Grade X can usually be manufactured from West Texas crude, particularly if the West Texas crude can be blended with a small amount of distillate from Mid-Continent crudes. We understand that Grade X, which is specified for operations in cold climates, is more difficult to procure than Grades A and B.

It is easy to see from the above brief resumé of petroleum products manufactured from West Texas crude that there are certain disadvantages in blending West Texas crude with Mid-Continent crude and then processing the blend. While such an operation might be entirely satisfactory from a strictly operational standpoint, the mixed products would certainly be advisable to process each type of crude separately, then blend the products to meet customer requirements.

Crude Storage

After thorough consideration of West Texas crude oil from the standpoint of analysis and products, we next have to consider storage of crude oil prior to first distillation. Storage-tank corrosion from high-sulfur crude is mainly the result of breakdown of hydrogen sulfide when mixed with air, forming elementary sulfur and water. Naturally, all storage tanks should be effectively sealed regardless of the type crude stored, but with crude containing large quantities of hydrogen sulfide, sealing to prevent air entrance is of more importance. Disregarding this relationship between air and hydrogen sulfide, it can be generalized that the greater the amount of hydrogen sulfide, the more corrosion in the storage tanks. Therefore, the worst corrosion is in the producer's tank where the crude contains the maximum H_2S, and usually the least attention is given to breather valves, etc. Corrosion is progressively less

from producer's tank to pipe-line gathering system and thence to refining storage. We have 3/16-inch steel roof on storage tanks in crude-oil service for 8 years.

Safety Precautions

Anyone considering the use of West Texas crude oil should secure a number of copies of United States Bureau of Mines Bulletin 231 entitled, "Investigation of Toxic Gases from Mexican and Other High Sulfur Petroleum and Products." This booklet is very good for educational programs in connection with the hazards of hydrogen sulfide. The danger of hydrogen sulfide is obviously in proportion to the amount of gas present. This danger is of course greatest in production operations and decreases as the crude loses hydrogen sulfide during transportation. Crude-oil storage tanks in the refinery contain a high percentage of hydrogen sulfide. Operators who have occasion to open gauge hatches of crude-oil tanks should be cautioned concerning inhaling the poisonous hydrogen sulfide fumes. It is also advisable that vapor-recovery lines from crude tanks be disconnected from vapor recovery. As pointed out in other sections of this paper, hydrogen sulfide besides being corrosive and poisonous will cause all products, even the finished gasoline, to become unsatisfactory for use due to direct absorption of hydrogen sulfide. At other points where hydrogen sulfide will be particularly evident will be in connection with the non-condensible gases from cracking still which the usual refiner uses as a fuel. This gas will contain a high percentage of hydrogen sulfide and will require the usual precautions.

I am acquainted with the circumstance of only one fatality from hydrogen sulfide gas in a refinery. That happened 12 or 14 years ago when the caustic that had been used in scrubbing the hydrogen sulfide from straight-run gasoline was dumped into the plant sewer lines. Acid sludge from another portion of the plant was dumped into the same sewer system. The reaction between the sodium sulfide and sulfuric acid resulted in the release of a large volume of hydrogen sulfide. This release of large volumes of hydrogen sulfide resulted in the death of a pump mechanic who was not aware that the volume of hydrogen sulfide had been materially increased. It is sometimes difficult to explain to workmen that hydrogen sulfide in the pure form is actually an odorless gas and that it is only the low concenrates that are so noticeable.

Pre-Treatment of Crude—Desalting

Many refiners ask for information concerning a type of treatment that can be applied to the crude oil prior to processing that will eliminate the hazards of corrosion to the processing equipment. No such treatment has yet been made available to the refining industry. However, almost all operators who are using West Texas crude have some type of desalting operation prior to first distillation.

Hydrogen sulfide that is present in the crude oil will combine directly with metals to form iron sulfide, but such a coating is actually a protective coating and additional corrosion due to sulfur will not occur unless this sulfide coating is removed. The magnesium and calcium chlorides present in the crude oil tend to break down at the temperatures of ditillation, forming hydrogen chloride gas that is very corrosive and will immediately remove the sulfide layer so that the principal corrosion in the first distillation is first conversion of the metal into an insoluble sulfide and then the solution of this sulfide by hydrochloric acid. Effective desalting will decrease the formation of hydrogen chloride and thus decrease corrosion.

Mid-Continent refiners of West Texas crude will have one definite advantage over those refiners who process the material in West Texas. For instance, one of the most efficient ways to remove salt is through the use of electrical desalting.[8] This electrical desalting requires the addition of some fresh water to the crude, then the total water content is precipitated in the electrical precipitator. This usually results in removing of from 90 to 95 percent of the salt and filterable solids, some H_2S, and elementary sulfur. For this operation to be effective, the fresh water that is added must be low in salt content. There are several regions in West Texas where the fresh water used in refining process will contain more salt than is contained in the crude oil. Under such conditions the only possibility is to desalt through heating of the oil, permitting the water and salt to settle through one of the so-called "gun barrel" settlers. The removal of this salt reduces the coke deposit in all parts of the first-distillation heaters and has a very definite bearing upon corrosion.

First Distillation

The next statement may be controversial in the minds of some West Texas refiners and there are certainly at least some minor exceptions, but *generally speaking no special alloys are required in the crude dsitillation equipment for satisfactory service and reasonable life of equipment.* At the usual temperatures of first distillation there is no excessive corrosion in the heater tubes or headers. As a matter of interest the crude fractionating column that is at present in service in one of our plants was installed in 1927 with a shell ½-inch thick at the start. It is now ready for replacement. Pumping equipment is one exception to the statement concerning alloy metal. From the standpoint of mechanical efficiency and reduction in maintenance to pumps, pump packing, etc., we are using 18-8-chrome-nickel-covered rods, valves and seats on a hot-oil crude charge pump (275° F.) and 18-8-chrome-nickel-covered rods on the hot tar pump (550° F.). We also find it an advantage to use alloy metals on gasoline reflux pumps. We are using monel rods and Dura-bla valves with "Ni-Resist" liners and pistons. Condensing equipment is cast iron, heat exchangers are steel with admiralty metal and steel tubes. After-coolers on gasoline are steel shell and tubes.

As mentioned in connection with the necessity of desalting, the point of principal corrosion in distillation of sour crude is in condensing equipment. If the crude has been thoroughly desalted, the quantities of ammonia required will be less; however, it will still be necessary to add some ammonia into the first distillation vapor lines and condensers. We use aqua ammonia pumped by centrifugal pump from storage. The aqua ammonia is measured by a Rotometer. It is introduced on the top fractionating deck of the crude oil fractionating column. Introduction at this point gives better distribution and takes care of corrosion that may be accelerated at the point where reflux is added. We control the quantity of aqua ammonia by maintaining a Ph.8 on the condensate water. This is checked hourly by the use of a Universal indicator by the stillman. Once daily a check is made with the

electrical potentiometer in the laboratory as a means of checking the operator's interpretation of the Universal indicator. There are a number of other controls that could possibly be used. Indicators such as phenolphthalein and methyl orange have too wide a range for application to this problem. We operated

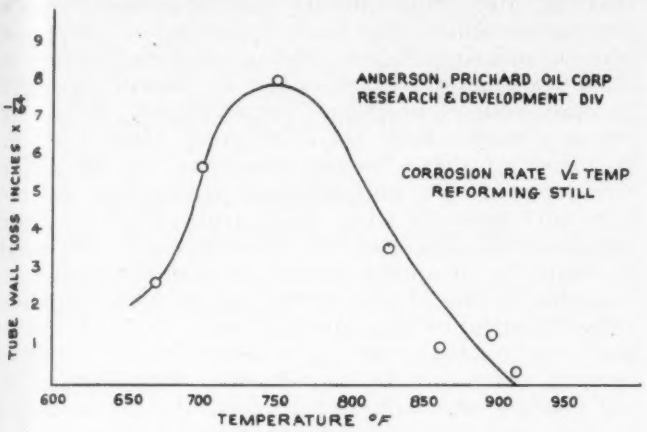

FIGURE 2

successfully for a number of months by checking the condensate stream for iron with a common potassium ferrocyanide quantitative test for iron, setting up a column standard for maximum iron content allowed. We use from .015 to .03 pounds of aqua ammonia per barrel of crude. Much is said in current literature[9] concerning the possible formation of ammonia chloride that will plug vapor lines and tower. This is a problem and will require facilities for periodic water washing of the condenser coil.

It should be explained that the ammonia is used to neutralize only the hydrochloric acid present. The hydrogen sulfide is removed in the caustic scrubber between the condensing section and the run-down tank. If the hydrogen sulfide is efficiently removed there is no reason why there should be any more corrosion in the distillation run-down tanks than there would be with the unit operating on sweet crude. Likewise, in finished storage tanks there is no reason for corrosion, at least not any more reason for corrosion than there would be under operations with a sweet crude. There have been references in literature to mercaptan sulfur corrosion,[10] as well as some reference to other types of sulfur compound; however, so far as we can determine all corrosion in crude oil tanks is due to hydrogen sulfide, either directly or indirectly.

Efficient and thorough scrubbing of the gasoline stream prior to entering the run-down tank is very important. If a refiner is equipped in the usual manner with vapor-recovery connections to run-down tanks, the presence of hydrogen sulfide in the run-down tank will pass from the run-down tank into the vapor lines and may even be absorbed into all other tanks, finished gasolines included. The amount of caustic used for this scrubbing varies with the efficiency of the scrubber and the actual hydrogen-sulfide content of the crude. It is possible to remove hydrogen sulfide with .2 or .3 of a pound of caustic per barrel of crude charged.

Cracking Still

Corrosion becomes a serious problem in cracking still units or vacuum still units, or any place where it is necessary to heat the charging stock to above 675°. We know that increased corrosion which we call "hot corrosion" starts at approximately this temperature and increases with increases of temperature, depending somewhat upon the exact nature of the charging stock.

In Figure 2 we show corrosion rates versus temperatures as measured from tube to tube in the heater of the reforming still. The exact shape is of no significance except as it is related to the heater from which the data was collected. In other words, changes in pressure and temperature will have an effect upon the exact crest of this curve; also the type of charging stock processed in a given heater will materially affect the shape and crest of this curve. The important feature is that such a relationship can be established for almost any heating unit. The data for constructing such a curve necessitates very careful inspection, which, in itself, is good training for plant inspectors. Once the data is collected it provides a direct clue to the points of maximum corrosion. It will show where alloy steels would be of maximum benefit, etc.

Our cracking plant equipment contains several types of alloys and some regular carbon steel as follows:

All tubes, return bends and hot transfer lines are 18-8 chrome nickel. The vapor column has a lining of 11-13 chrome steel spot welded to the steel shell. The soaking chamber is lined with a composition material that both protects and insulates the vessel. The hot oil circulating pump is 11-13 chrome. *Incidentally, we have found no measurable corrosion of 18-8 chrome nickel steel in any sour-crude operation regardless of temperature.* The fact that 18-8 chrome nickel steel costs at least 12 times as much as regular steel is a very real barrier against extensive use of this metal. Starting with the vapor line from the vapor column, all beyond is ordinary carbon-steel equipment. No neutralizing agents are used in the cracking plant condensing system.

Practically all refiners operating cracking stills on West Texas charging stock, who are not equipped with 18-8 steel in the critical zones mentioned above, use at least 4-6 chrome with the addition of lime to the cracking-still charge. We have been told that lime up to 1 pound per barrel has been used in combatting corrosion in the cracking still.[11] However, there will still be some corrosion at points where the temperature is above 700° F.

We believe that corrosion is a problem in almost any thermo cracking unit since very few crude oils are actually free of sulfur. The so-called sweet crudes merely have less sulfur than some of the others so that the use of charging stock with a high sulfur content will probably mean that corrosion will still occur at the same places where it has been noticed in previous operation, but can be expected to proceed at an increased rate. We have conflicting opinions expressed in literature as to which type of sulfur compound is the most corrosive. Marks states[10] that the mercaptan sulfur compounds are the most corrosive of sulfur products; however, we have been unable to prove that mercaptans are actively corrosive. Nevertheless, all corrosion problems that we have studied in connection with refining of West Texas crude have been corrosion in the presence of H_2S. The fact that so-called "hot corrosion" starts at temperatures around 700 or above can be tied to the fact that most West Texas crude will show some cracking action and hydrogen sulfide formation at the same temperature. Therefore, we expect corrosion at

any place where hydrogen sulfide is present and if lime is used to decrease corrosion in cracking units the degree of protection can be judged by the decrease in hydrogen sulfide content of the gas production. In one test that was made it was found that each 1 pound of lime added per barrel charging stock would reduce the hydrogen sulfide by aprpoximately 30 grains per 100 cubic feet of gas. No doubt this figure will be different for each type of cracking operation and will have other variables such as the actual quantity of sulfur present in the charging stock and the temperature or degree of cracking.

Obviously, all lime used in charging stock will eventually become a part of the tar production. In this respect it may render this tar unsuitable for fuel purposes, particularly in meeting requirements for sediment. There may be numerous methods of removing this lime from the tar. The possible use of filters is obvious. Some plants have a practice of contacting pressure-still tar containing lime with the carbon dioxide from stack gases, causing the precipitation of the lime as calcium carbonate. We have had no experience with any of these operations; therefore, we are unable to furnish any information as to the efficiency of any type of process used to remove lime.

Many refiners ask questions regarding the possibility of reducing corrosion by blending the high-sulfur-content crude with a crude of less sulfur content. While we doubt this would be advisable in the production of gasoline, kerosine and distillates, it might have beneficial effect on charging-stock gas-oils for pressure stills. We would expect that the possible benefits could be measured by quantity of H_2S in the gas production, the same as benefits of treatment with lime can be measured.

Other Parts of Distillation Equipment

No doubt many of you have gasoil stills or vacuum units used in the production of heavy distillates. Such equipment usually operates at temperatures above 675° F. and will be subject to corrosion the same as other points at high temperature in refining processing. Under such conditions you can expect corrosion on outlet tubes and vapor line. Here again, ammonia can be used to offset the corrosion cycles. If alloys are available it is advisable to line the tower with 11-13 chrome. In one such operation we used approximately .03 pound of aqua ammonia per barrel of charge.

Treating

You have noted that treatment with ammonia for hydrogen chloride and caustic scrubbing for removal of hydrogen sulfide has been treated under the heading of distillation. We believe that such treatments should be considered from the standpoint of corrective chemical treatment to eliminate corrosion. A treatment of the raw gasoline to render the product satisfactory from the user's standpoint will use about the same type process and the same equipment as used for treating cracked distillates from any refining operation. There is no need for any special alloys in any treating process that is carried out at temperatures below 675. As has previously been noted, any high temperature process will need alloy protection.

Sweetening Processes

The first treating processes for petroleum distillates containing sulfur were primarily processes used for odor improvement. Such processes are usually called "sweetening processes." Practically every refiner who operates a cracking still also operates some type of sweetening process. These have been listed[12] as doctor treating, lead-sulfide treating, hypochlorite treating, and copper-chloride treating.

All of these processes convert mercaptan sulfur (that is, the strong odor sulfur compounds) into a mercaptide sulfur that has reduced odor. There are many conflicting claims concerning the efficiency of these various processes. Each is dependent upon accurate control procedure for efficiency. When we are confronted with the conflicting claims of the efficiency of these various processes, we are often reminded of the philosopher's conception of the difference between a fact and a truth. I believe little detailed explanation of this difference will tell what is meant by adequate control. For instance, it is a fact that if one of the several processes mentioned above is installed in a given refinery that previously used one of the other processes without accurate control, there will be considerable improvement in the product and reduction in cost. It may be noted as increased susceptibility, decreased corrosion, etc. This improvement is usually due to improved control technique.

In doctor treating and lead-sulfide treating, it is very important that treating be accomplished without the addition of excess elementary sulfur. This can be accomplished by the use of butyl mercaptan test procedure as described in the U.O.P. manual of laboratory test methods.[13] If sulfur addition is controlled to the minimum, there will be less tendency and possibly elimination of the formation of polysulfides that are so detrimental to lead susceptibility.

Likewise, if copper chloride process is used there must be an absolute guarantee that copper compounds are not allowed to remain in the gasoline, forming metalo-organic materials that are very active catalysts for gum formation. Thus, it may be a fact that a change from one process to another results in improved products at less cost, but the truth is that improved methods of control of process are the chief reasons for the improvement—not the new process.

We believe there is very little discussion needed on hypochlorite treating. Our experience has shown that hypochlorite treating is seldom effective for mercaptan content above .03. Also, it is obvious that hypochlorite treating would not be used on a cracked distillate due to the possibility of chlorinating the olefine and diolefine contents.

Treating West Texas crude oils for mercaptan content will not necessarily need to change your methods of treating. However, it will change the degree and properties of everything about treating. Chemical costs will increase in proportion to the increased sulfur content. All constituents of a treating process will need to be considered from the standpoint of increased efficiency. For instance, if you are using a process where it is necessary to add air to furnish oxygen for one phase of the process, you will probably see that 10 to 20 times as much air will be needed for treating the materials of high-mercaptan content. This increased volume of air will add a new problem of vapor loss. It is difficult to compare treating costs on high-sulfur distillates with that of low-sulfur distillates since there are so many variations in the actual type of product treated, but it is safe to estimate that the costs will be at least double the cost of treating so-called sweet distillates.

Sulfur Extraction Processes

The manufacture of high-octane gasoline has brought into focus the effect of sulfur content upon increase in octane by the use of tetraethyl lead. Figure 3 shows the relationship and Hebyl susceptibility for straight-run and cracked gasolines of varying sulfur contents. All types of sulfur compounds

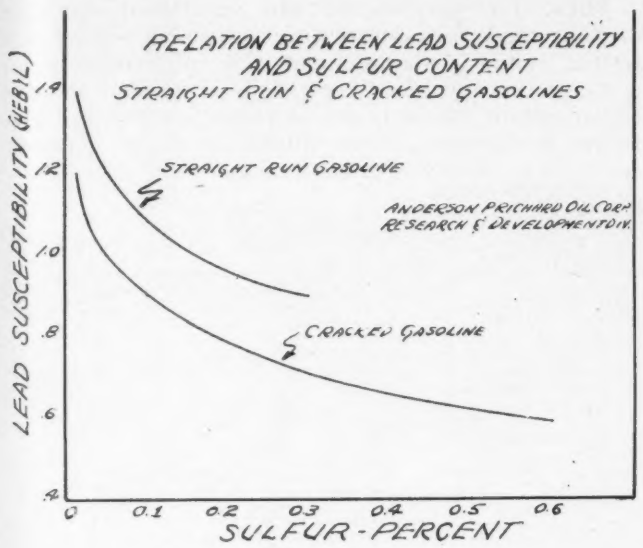

FIGURE 3

have a tendency to decrease tetraethyl response to some degree. Of course, free sulfur in the elementary form as it might be found due to inadequate control of one of the sweetening processes or hydrogen sulfide which in any modern refining operation would never be found in a finished product, are the most detrimental to lead susceptibility, but sulfur in the form of mercaptans and disulfides is the usual sulfur compound present and thus most detrimental to the activity of tetraethyl lead. Therefore, a number of processes have been developed that remove all or portions of these sulfur compounds. Sulfur in the form of thiophenes fortunately is not nearly so detrimental since it would be much more difficult to remove. Sulfur extraction processes can be listed as follows:

1. Caustic scrubbing.
2. Caustic scrubbing plus some type of activator to improve the efficiency of caustic scrubbing.
3. Sulfuric acid..
4. Removal of disulfide by redistillation.

Figure 4 has been so drawn as to emphasize the importance of removal of mercaptan sulfur compounds from gasoline. Please note that this figure refers specifically to the production of 72-octane gasoline. Notice that there are three curves representing three different sets of data. A variation in the petroleum products tested should cause a definite variation in the effect of small amounts of mercaptans. Perhaps this accounts for the differences between the three curves. However, we believe there is a definite difference between the three curves and that the composite data is very useful in estimating the value to the refiner of any of the sulfur extraction processes.

Straight caustic scrubbing of West Texas gasolines is very effective. Caustic scrubbing by the use of special activating agents, such as potassium isobytrate or methanol, have been thoroughly described in literature.[14, 15] Also, sulfuric acid is very effective with West Texas gasolines. Incidentally, sulfuric acid has a very complex action upon petroleum distillates, depending upon the strength of the acid and the quantity present. It actually has a sweetening action in some respects, changing mercaptans to disulfides. However, there are many other actions such as re-solutions of these disulfides and polymerization, which together give effective treatment. Sulfuric acid treatment has been covered in detail by Waite and Aitken[16] in recent literature.

The fourth process listed above is not so well known; however, reference to it has appeared in literature several times within the last few years. By the use of any of the sweetening processes mercaptans are converted to disulfides. In so doing, the boiling point is materially increased so that careful redistillation will leave the disulfides in the bottoms. Redistillation after acid treating performs the same function and provides effective sulfur removal.

Vapor-Phase Treating

One of the most efficient methods of treating high-sulfur distillates is by one of the many vapor-phase treatments using fuller's earth, clay or bauxite as a catalyst. Most of these processes are accomplished at temperatures above 650. Therefore, the refiners are again faced with the problem of combating corrosion. This corrosion is in all respects comparable to the corrosion in cracking operations. These vapor-phase processes are known by various trade names such as "Gray Process,"[17] "Perco Process,"[18] and "Houdry."[19] One West Texas refiner reduces straight-run gasoline from a sulfur content of .2 percent to below .05 percent by using a West Texas

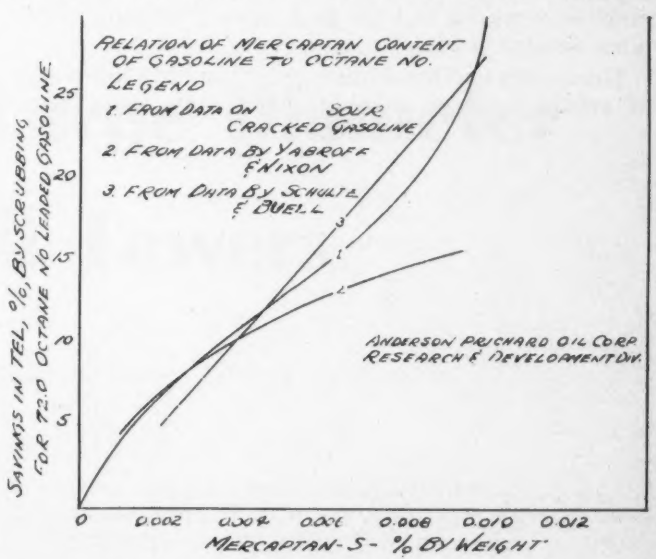

FIGURE 4

clay as a catalytic agent.[20] The removal of sulfur by one of these methods usually increases the clear octane number by at least two points. There is also a definite increase in lead susceptibility that gives another increase from 4 to 6 points in octane, depending upon the quantity of tetraethyl lead used. Table 3 shows the inspection of a West Texas gasoline before and after desulfurization.

Maintenance

If it were desirable to express the difference between operation on West Texas crude and Mid-Continent crude in one word, that word would be

TABLE 3

West Texas Straight Run Gasoline

ASTM Octane Number	Undesulfurized	Desulfurized
+0 cc TEL	61.8	64.3
+1 cc TEL	69.9	74.8
+2 cc TEL	74.4	79.6
+3 cc TEL	77.5	82.5
ASTM Distillation, °F.		
First Drop	104	103
5 Percent Evaporated	138	137
10 Percent Evaporated	161	160
20 Percent Evaporated	190	188
30 Percent Evaporated	211	208
40 Percent Evaporated	227	225
50 Percent Evaporated	243	242
60 Percent Evaporated	259	258
70 Percent Evaporated	277	276
80 Percent Evaporated	297	297
90 Percent Evaporated	326	323
95 Percent Evaporated	346	342
End Point	380	381
Recovery, Percent	98.0	98.0
Residue, Percent	0.5	0.6
Loss, Percent	1.5	1.4
RVP, psi	7.05	6.90
Gravity, °API	56.3	56.3
Mercaptan Sulfur, Percent	0.058	0.001
Total Sulfur, Percent	0.149	0.019

"maintenance." To treat the subject adequately would be a subject for another paper. Many specific points concerning maintenance were indirectly referred to above. However, it can be said without any possibility of contradiction, that every phase of maintenance will be higher, possibly two or three times the cost of the same phase of maintenance for sweet-crude operations.

A larger and better trained maintenance personnel will be necessary. All inspections must be in more detail and will thus require more time and attention. Each oversight or mistake in inspection will be more expensive. The old axiom, "A stitch in time saves nine" is working in high gear during refining operations on sour crude.

Mechanics and machinists must not only know how to repair a given machine, but they must know exactly what type metal the machine is composed of and how to work with that particular alloy. The alloy metal in each pump rod will cost 12 times as much as a carbon-steel rod.

One of the most critical needs will be the need for welders, with training and experience necessary to weld alloy steel.

Thus, it is easy to see why successful operation on sour crude costs more and requires increased skill in the refinery management. As compensation for some of this increased cost is the truth that some of the resultant products are of better quality and give better performance than similar products manufactured from Mid-Continent crude.

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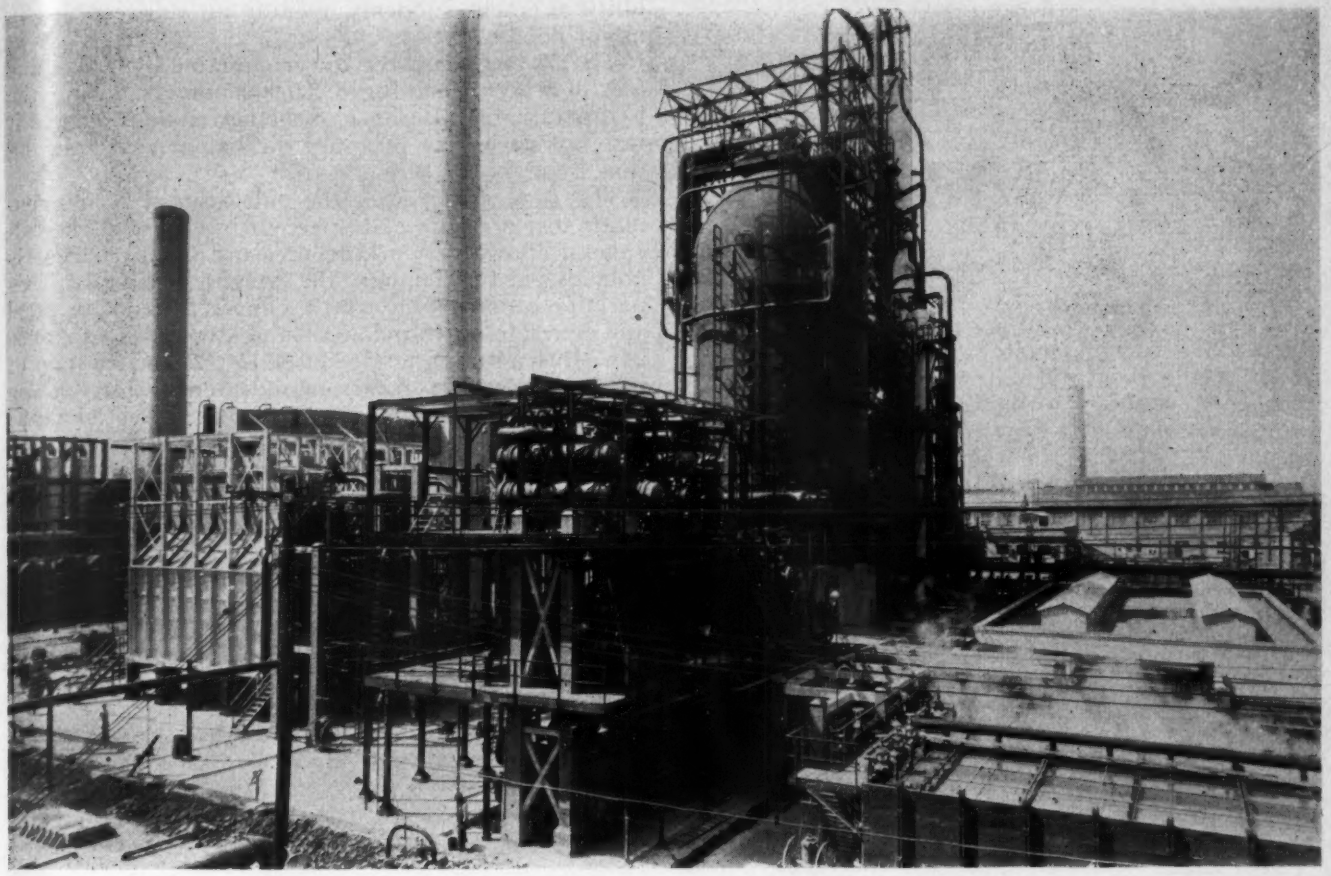


Advantages of Large Diameter Crude Still Towers

E. F. BRUMMERSTEDT, Mechanical Engineer, Foster Wheeler Corporation

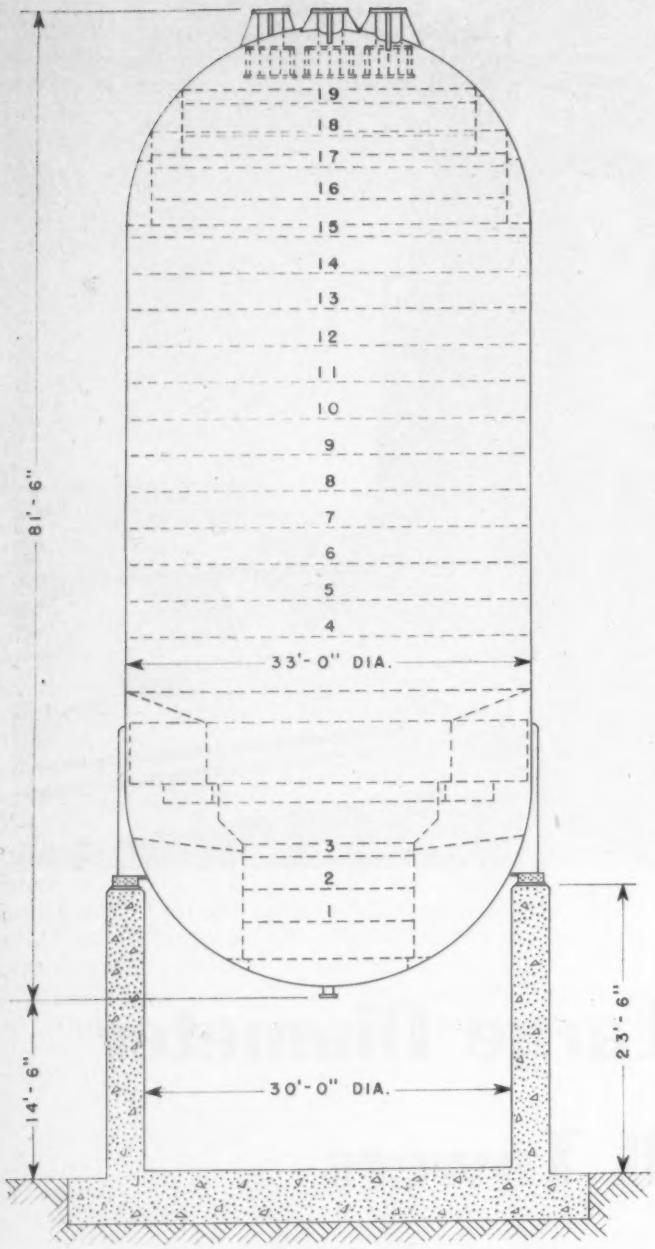
THERE has been a consistent increase in the size of distillation units installed in petroleum refineries, especially the vacuum towers. A study of the factors that justify the erection of larger towers is of interest.

The largest tower in this country, according to available information, is a 33-foot diameter vacuum unit used in conjunction with a crude still having a capacity of 37,000 barrels per day. Construction of such a tower presents engineering problems that may cause some speculation as to the relative merits of one exceedingly large unit as compared with two or more smaller towers which have the same total capacity.

There are definite economies to be made by the construction of large towers, and their use, as contrasted with multiple, smaller-sized tower units. As to the performance of the large size units, the 33-foot tower has been in successful operation since May 1, 1943, and is yielding refinery products in accordance with calculated expectations. Since this appears to be the largest vacuum tower in the country, it forms a basis for comparison in studying the economics of towers with increased diameters.

With the experience gained from previous large towers varying from 18 to 25 feet in diameter, no problems were insurmountable in the design of the 33-foot tower, neither will there be any in the design and construction of towers 40 feet or more in diameter. Many regenerator chambers approximately 40 feet in diameter have been, and are being, constructed for fluid-catalyst cracking units.

The API-ASME code committee has modified its stress-relieving requirements for large-diameter towers so that it is now possible to build these vessels in the field without a mandatory furnace stress-relief. (See Par. W-463 in 1942 Addenda to the API-ASME Code.) This is a progressive movement to speed construction with present capacity shop conditions. As a



substitute for stress-relieving requirements, the fabricator can still get a code stamp on his large vessel through relieving stresses by mechanical peening as described in Appendix J of the new Code Addenda. This does not imply, however, that peening is in all cases a satisfactory substitute for thermal stress-relief. Thus, it is now possible for field welding crews to fabricate large pieces of equipment in the field in very short time from prefabricated pieces with a minimum of shop labor. Progress in the science of welding, in addition to the large increase in the number of skilled welders, has resulted in many feats of welding construction during the present emergency that were not considered feasible several years ago.

Another Code concession for large field-fabricated towers is contained in the new footnote under W-525 of the Addenda, which allows the hammer test to be applied to vessels over 12 feet in diameter before the hydrostatic test, with the tower filled with air at atmospheric pressure. This enables flagrant imperfections in the welded seams to be discovered before filling the vessel with water, and thus avoids the possibility of cracks suddenly opening up and resulting in minor floods.

The 33-foot diameter tower contained 58,000 cubic feet of water weighing 3,260,000 pounds during the hydrostatic test. Because of the new code provision it was not necessary to apply the hammer test during this stage.

The code also allows the substitution of a pneumatic test pressure of 10 percent in excess of the calculated allowable working pressure for large vessels not designed to support the weight of liquids. This permits construction which effects savings in steel and concrete for foundations and structural supports, as well as a saving in steel used in the construction of the vessel itself. However, many erectors prefer to use a hydrostatic test as a safety measure, as was the case for this tower.

The actual savings in construction of one large tower as compared with two smaller towers of equal total fractionation (tray) area, is brought out by a direct comparison of the costs in each case. The 33-foot tower has a total tray area of 12,952 square feet. The net estimated cost of two 24-foot-diameter towers of the same height and having a total equivalent tray area is compared to the single tower in the following table:

Comparative Cost

ITEM	ONE 33' I. D. TOWER		TWO 24' I. D. TOWERS	
Tower Shell	800,000 # @ .15	$120,000	1,000,000 # @ .15	$150,000
Tower Trays and Supports	450,000 #	92,500	500,000 #	100,000
Foundation	500 cu. yds.	20,000	700 cu. yds.	28,000
Insulation	8,500 sq. ft.	10,000	11,000 sq. ft.	13,000
Steel Platforms, Etc.	20,000 lbs.	3,000	30,000 lbs.	4,500
		$245,500		$295,500

This shows that the direct savings on the tower alone amounts to $50,000. In addition, there is a saving on the auxiliary equipment required for the operation of the second unit (of the two-tower unit) including such items as the pumps, heat exchangers, piping and instruments. This saving would equal approximately the cost of the tower. In addition, a plant with only one tower would require a smaller ground area which would result in a more compact and efficient unit to operate, thus effecting a saving in operation and maintenance expenses. Another reduction would be in erection time, an item dependent upon the number of pieces of equipment installed. This conservation of time alone probably would result in advancing the completion date by one or two months over that required to erect the two-tower unit. At this war period when refinery products are at a premium, any such saving is of even more importance than that of the direct reduction in cost.

Taking all items into consideration, therefore, the total estimated savings obtained by using one 33-foot-diameter tower as compared with the installation of two 24-foot-diameter towers for processing approximately 50 percent of the crude charge would be about $100,000. This is exclusive of operation and maintenance expenses.

This cost reduction of approximately $5.50 per barrel for 50 percent of the crude charge, immediately overshadows any uncertainty as to construction and operating difficulties and had an important bearing on the final decision to proceed with the single large tower.

The accompanying drawing and photographs indicate the result of decision to install the large tower. Wartime restrictions prohibit disclosure of the owner's identity and of the plan location.

New Uses for Solvent Processes

GEORGE F. FITZGERALD

THE petroleum industry has adopted and perfected many processes during its development into a notable chemical industry. Typical of these are superfractionation, alkylation, isomerization, hydroforming, catalytic cracking, solvent dewaxing and extraction. Most of these processes have undergone years of modification and evolution, culminating in their widespread acceptance by progressive refiners. Engineering developments in the period immediately prior to the war have been very fruitful especially in the fields of cracking and lubricating-oil manufacture.

This accumulated experience has controlled and directed the manner of solving problems brought on by war demands. Processes which have been serving one distinct purpose are being adapted to quite different use. Where a single process is inadequate, suitable complementary methods are coupled with it. For many years high-purity light hydrocarbons have been produced on a large scale. Superfractionation made this possible but could not furnish the complete answer to the rubber program's demand for pure butadiene.

For polymerization with styrene to form Buna S, butadiene must be free from butylene and side-reaction products of the dehydrogenation of butylene. The boiling points of these products are so close together that fractionation alone will not effectively separate[1] them. It is now apparent that solvent extraction processes are doing[2,3] the job and doing it well. As will be readily understood, wartime restrictions make it impossible and undesirable to go into detail. Much can be said, however, about solvent processes in general and the methods which are applicable to production of high-purity chemicals from petroleum. A study of the subject will show that the principle is the same whether extracting lube oils or toluol.

It is only natural, then, that past experience would suggest the use of solvents for purifying butadiene and toluol. The oil industry has enjoyed extremely gratifying success in its application of solvents to the improvement of lubricating oils. Here the problem is to remove anywhere from 5 percent up of undesirable components. In this general sense wax and petrolatum rank with non-paraffinic hydrocarbons as undesirables in high-grade lubricants. In other words, solvent extraction and dewaxing are both purification processes.

The American petroleum industry has had the benefit of the country's finest engineering talent in developing these solvent processes. Each new installation is taken as an opportunity to make improvements and to correct earlier errors. Anyone who has visited, for example, one of the early solvent dewaxing plants and then compared it immediately with one of late construction readily appreciates the difference. Close cooperation between refineries and engineering contractors makes it possible to give everyone the benefit of the latest advances. Under such circumstances, solvent methods have become highly perfected. For the sake of completeness, leading methods will be reviewed briefly.

The earliest commercial extraction process employed liquid SO_2 and was successfully applied first to kerosine and then to lube oils. No chemical reaction was involved because the operation depended entirely on physical solution and separation of the oil and its impurities. If the extracted impurities were blended back with the refined oil (or raffinate) the original charge stock would be reproduced. Such is not the case where chemical reaction takes place, as in sulfuric acid treating.

One of the early improvements in the liquid SO_2 process was the addition of benzol. This increased the solvent selectivity range so that more types of undesirable components could be removed. The use of mixed solvents is common today in such processes as benzol-ketone dewaxing, duosol (cresylic acid-propane) extraction, and with added portions of water, the broad selectivity of phenol.

Choice of solvent depends upon cost, availability, selectivity, adaptability to the particular charging stocks, stability and ease of recovery. A solvent must be selected which is suitable for the stocks to be handled and the equipment must be designed to give the equivalent of many stages of extraction. It is important to remember that the right solvent will give better results if applied in separate small doses rather than all at once.

All solvent extraction processes depend upon one general principle[4] of operation. Their purpose is to separate a mixture of different types of hydrocarbons. These types may be aromatic, naphthenic, paraffinic or any combination. Each type displays a different degree of solubility in a given solvent at a given temperature. By varying the temperature and the amount and kind of solvent, the extraction process can be made to work on almost any commercial stock. As we will see shortly, an understanding of the general principles of solvent extraction simplifies its application to pure chemicals as well as lubricating oils.

Countercurrent solvent extraction may employ single solvent such as SO_2, chlorex, furfural, and nitrobenzene, or double solvents such as those already mentioned. Where a single solvent is used it is ordinarily one with a strong affinity for asphaltic hydrocarbons. Extraction is accomplished by passing oil and solvent through the contacting system in opposite directions. The incoming charge meets solvent which is partly saturated with extract material but the outgoing partly-extracted oil meets the freshest solvent and thus gets maximum washing just before leaving the system.

In the case of double solvents, they must be prac-

tically immiscible and one must have a strong affinity for paraffins, the other for non-paraffinics. They enter at opposite ends of the system, with the paraffin solvent entering where the non-paraffinic solution leaves. The charge oil is introduced at an intermediate point. For example, the Duo-Sol process, using propane plus a phenol-cresol mixture, operates in this way.[5] The propane dissolves the paraffinics and the cresol content governs the solubility for asphalts while the phenol content is adjusted to permit extraction at normal temperatures. Raw stock is charged at an intermediate stage so as to permit removing the paraffinic fraction at the point where the cresol is introduced. Likewise the non-paraffinic fraction is removed where the propane enters. The two phases are separated by gravity settling. This arrangement of counterflow makes for the most effective use of solvents and insures intimate contact without excessive agitation or danger of emulsions.

A packed tower gives the effect of many stages which would otherwise require a battery of treating and settling tanks.[6] Every effort is made, both in design and operation, to insure complete use of solvents and at the same time clean separation of raffinate solution from extract solution. The more valuable or scarce the charge stock, the more pressing becames the question of clean separation. Desirable as that is in the case of high-grade lubricating oil, it is of paramount importance in the wartime production of high-purity butadiene and toluene.

Next in order after extraction and separation comes solvent recovery. It is at this point that many early designs and installations failed. The extraction must be thorough, and the separation must be clean, but without economical solvent removal an extraction process cannot pay for itself. Factors involved are not only loss of solvent but also product degradation and decreased throughput.

In commercial plants the raffinate solution and extract solution go to different distillation units and the separated solvents return to the system. Both direct-fired heaters and closed steam are used in conjunction with flash towers and steam strippers. All steam condensate is collected and stripped of its solvent content.

So far as published information goes, butadiene extraction is being conducted mainly with single solvents. Of the extraction agents used many are probably common industrial chemicals while others are much less familiar. At the Baton Rouge refinery[1] a "special solution" is being used. Butadiene is produced there from five separate plants. The one just completed is the first large government-financed plant to go on stream employing the so-called standardized butene-dehydrogenation process.

Isolated statements[7] refer to the use of furfural and methyl cyanide as solvents for butadiene. By their use butadiene may be extracted from side-reaction products which would render it unfit for polymerization to form synthetic rubber. Demonstrating that well known solvents can be given new application, turpentine[8] is a very effective butadiene solvent. The impure butadiene mixture is scrubbed countercurrently in a tower packed with petroleum coke. The turpentine enters the top of the tower, drops through the ascending charge in the form of a spray and extracts the butadiene during the passage. The unabsorbed gases are used as fuel and the butadiene is readily recovered from solution by distillation and the turpentine recycled.

A novel extraction medium is described in a recent patent.[9] Diolefins such as butadiene are removed from hydrocarbon mixtures by extraction with a complex solution of a copper salt such as cuprous chloride, in a water solution of an organic nitrile such as acetonitrile. Ethylene glycol or similar solvents may be substituted for water in the mixture. Extraction takes place at 50° F. after which the enriched solvent is heated to 160° F. to distill off the butadiene. The solvent is said to be capable of absorbing 4 cubic feet of butadiene per gallon at 50° F.

The purification of chemicals from petroleum need not be limited to solvent processes already in use in refineries. A case in point is the peculiar operation known as azeotropic distillation. It has been used for many years by the wood chemical industry[10] to produce pure acetic acid. Butyl alcohol is added to the dilute acetic acid. On heating the butyl alcohol and water distill over as a constant boiling (or azeotropic) mixture, leaving concentrated acetic acid in the still. When the still vapors are condensed two layers are formed from which the alcohol can be recovered by redistillation.

This same principal can be used in effecting almost complete separation of pure toluene from petroleum fractions. Among the many solvents suitable for the purpose are methyl alcohol, ethyl alcohol, methyl cyanide and methyl ethyl ketone. The latter is the well known chemical used with benzol in solvent dewaxing. In the production of toluene or any other aromatic from petroleum it is first necessary to concentrate the desired chemical into a narrow cut by fractionation. When the proper azeotrope former is added to the cut containing paraffins, naphthenes, and aromatics it forms constant-boiling mixtures[11] with all three but the aromatic mixture will have the highest boiling point. After the paraffins and naphthenes have been distilled off, the solvent can be recovered from the overhead and bottoms by extraction with water, in which it is soluble. The solvent is then distilled from the water and recycled.

Most of the details of actual processes in current use for the production of pure chemicals such as butadiene and toluene will remain unpublished until after the war. Obviously such important wartime secrets cannot be made public. From what has appeared in the literature, it is evident that large-scale production of pure chemicals from petroleum will continue on a permanent post-war basis. There is even some discussion as to its probable effect upon the coal-tar-products industry. It is clear also that the use of solvent methods in petroleum refineries is due for continued expansion.

The demands of war for all petroleum products with special emphasis on high-purity chemicals has greatly expanded the field of solvent processes. It has become necessary to make thousands of tons of butadiene and toluene where little or none was made before. The petroleum industry accepted the responsibility and is discharging it. The success of the program has depended to a very great extent upon the use of solvent extraction.

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[4] Rossini, Petroleum Engineer, February 1943, p. 51.
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[6] Varteressian & Fenske, Ind. & Eng. Chem., August 1936, p. 928.
[7] Arthur D. Little, Industrial Bulletin, April 1943.
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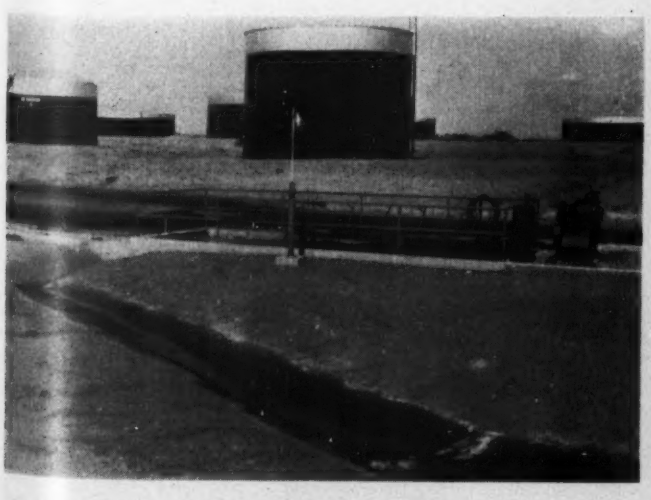
Automatic Waste Oil Skimmer

REMOVING the last trace of oil from waste leaving the yard of Continental Oil Company's plant at Wichita Falls, is accomplished by a three-compartment basins. All refinery waste, except residuum with a gravity approaching that of water, passes through the apparatus. It is of concrete construction and built at the head of natural drainage in the plant yard.

The largest basin is 10 feet wide, 25 feet long and eight feet deep and is itself divided into three sections. The second basin is for receiving skimmed oil and is equal in length and depth with the first section but only four feet wide. The third section is a bail flume, attached to the outlet of the main section, being 20 feet long and 30 inches wide and 40 inches deep. It likewise is divided into three compartments, each with a removable screen.

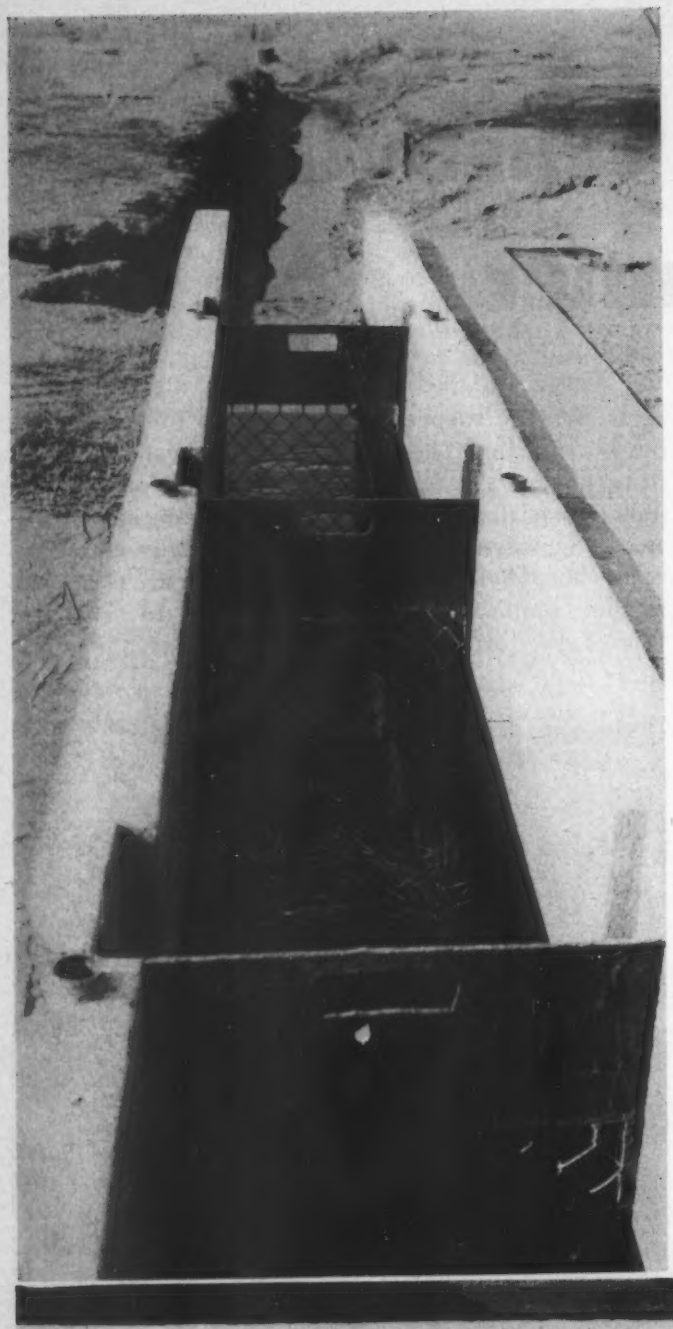
A system of plant drains empties into a common pipe line that in turn enters the first compartment of the skimmer. Instead of emptying directly on the surface of the liquids, the pipe is equipped with a downcomer that reaches almost to the floor of the unit, so heavy material is deposited in the lowest part.

All fluid rises from the floor of this compartment to flow over a low retaining wall which prevents passage of the heavy foreign matter, into the second part of the compartment. The next wall rises to the same height as the walls of the unit itself, but has a relief passage to permit flood waters to pass without overflowing. The lower end of this wall is slotted to permit only water and entrained oil to pass to the next compartment. The principal separation of oil from the waste water is obtained in this compartment, but, obviously, some of the oil will be carried further. Baffle walls, and compartment divisions are carried out further and at the end of the unit, only



The waste skimmer at the Wichita Falls plant of Continental Oil Company is placed so as to get the advantage of natural yard drainage.

The first compartment, showing split pipe across the body of waste to remove skimmings. The horizontal suction swing is used for removing all material when the unit is being cleaned.



water rises from the bottom, to flow to the third section of the unit.

Skimming devices are placed across the three compartments of the main section to remove the oil as it accumulates on the surface of the water. The skimmers are made by splitting convenient lengths of light 8-inch pipe to form a trough. One end is closed with a flat weld, and is supported in the surface of the liquid with a trunnion bearing in the concrete wall. The other end is closed with a flat plate, into which a 4-inch nipple is welded which is screwed lightly into a collar attached to a nipple passing through the wall which divides the main section from the section provided to receive the skimmed oil. Long control handles are welded to the skimmers so that they may be rotated back and forth, to allow the oil to be skimmed from the surface, and at the same time allowing the oil to flow to the oil section.

The third section, provided with screened doors, effectually prevents the rainbow from leaving the unit. Up stream from the screens, a handful of straw is dumped as frequently as necessary; oil which passes through the skimmer adheres to this straw. The clean water passes through the screens, and flows to the natural surface drainage to be disposed of through natural forces.

A motor-driven reciprocating pump is set on a concrete slab at the upper end of the unit to evacuate the compartments of oil, water and foreign matter. A manifold is set up with swings entering each compartment of the main section, controlled with gate valves so the unit may be drained and cleaned as found necessary. The same header is equipped with a suction line entering the oil section so that the skimmed oil may be pumped back to the plant.

A water line terminating at the side of the main section is equipped with hose and nozzle to flush down the sides and keep the equipment clean.

The tail flume (left) is fitted with removable screens. Upstream straw is kept in place so as to retain any minor traces of oil.

The dividing wall (below) later was provided with a hole to relieve the excessive flow of water during rains.

Response Ability of Gasoline to Various Concentrations of Tetraethyl Lead

REUBEN G. LOVELL
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THERE is an expression, composed of but two good English words, which, when used as it usually is, is considered to be an inane, slang phrase, not to be used by intelligent people. It is the contention of the writer, however, that the expression, "so what?" should be used to point up the analysis of every scientific fact, no matter how presented, nor by whom. Unless one can answer the question to his own satisfaction and to fit his own needs, the knowledge of the fact is of little practical value to him.

An enormous amount of research work has been done to determine the susceptibility of gasoline to the action of tetraethyl of lead but little has been done to answer satisfactorily the so whats? of the problem. For example, we have been told that sulfur in reasonable amounts was not, in itself, particularly harmful in motor gasoline; that the chief objection to its presence was the fact that greater amounts of Ethyl fluid were required to attain a given octane number. It is now generally known that some of the sulfur compounds are knocking compounds and that their reduction to a low percentage increases the lead response of the gasoline in a greater degree than has heretofore been considered feasible.

The objective has been to set a method of evaluating the knock tendency which would conform closely to actual road service conditions. Admirable as was the objective and in spite of the amount of arduous and expensive work done, thus far no definite correlation has been established between laboratory results and the reports of drivers of various cars under actual road conditions. The writer has better reasons than most for making the statement that the task was as hopeless as the effort to win an argument with a member of the gentler sex. For, so long as we have aspirated internal combustion gasoline engines powering our automobiles and being driven by some 25,000,000 people, most of whose impulses are under the influence of the go-getter school of thought, we shall be unable to evaluate accurately the characteristics of the fuel for these engines.

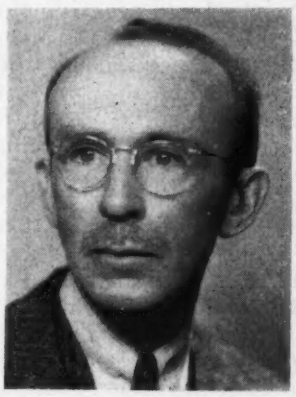
Application of Some Practical Methods to the Problem

Some years ago, with the idea of arriving at a more complete knowledge of the relation between gasoline characteristics and performance under all service conditions, we worked out the instrumentation shown in Figures 1 and 2. Let no one think that the project was as simple as would appear from the picture of the instrument panel. The idea, having no precedent in practice, had to be carried through the inevitable number of mistakes which, however, were accomplished on another and less costly car than the "loping laboratory" illustrated.

No means of registering knock intensity was found, however, which was more satisfactory than the trained ear. Nor would such a device have been of great value as one would think for, strangely enough, when the car was operated according to the indications of the exhaust gas analyzer, tachometer and intake manifold vacuum gauge, there was no perceptible knock under any ordinary road condition except at the point where the spark advance leaves speed control and goes under vacuum control. There is no difficulty in avoiding this point if one makes intelligent use of the gear lever and guides gear changes by tachometer, not by pride in the ability of his car to pull in high gear. The loping laboratory is equipped with automatic overdrive, careful use of which has been very effective in bringing out these points.

To relate a case in point will help to clarify the proposition and definitely is not a departure from the subject of this article, inasmuch as it is good evidence in support of the statement that our best efforts cannot hope to evolve an altogether satisfactory scale for evaluating motor gasoline which will hold good when the gasoline is placed in the tank of an automobile and used in an aspirated engine manipulated by that vague individual known as the average driver.

There is a stretch of well-engineered and well-paved highway some 6 miles in length from La Can-



R. G. Lovell

THIS is the author's first contribution to the columns of Petroleum Refiner and he feels that a brief outline of his purposes is in order.

From a background of many years experience he determined some time ago that he could best serve the readers of the refinery magazine by confining his writing to interpretations of the fundamental laws of science and of the many evidences of them which we all encounter in our every day work. The development of new scientific laws, or the repeal of the existing ones, can well be left in the hands of men of greater erudition but perhaps lesser practical experience.

He expects to comment from time to time, on the trends in refining practice as they come under his observation, with the hope that such comments will be of some value to men responsible for forming refining policies.

ada up Mt. Wilson in Southern California which offers an ideal proving ground for this purpose. The route is so well engineered that the grade is almost uniform for the entire distance. The grade percentage is such that a speed of 35 miles per hour can be maintained even in overdrive, but the intake manifold vacuum hovers between 0 and 3 inches, and an audible click from the engine can be heard almost constantly. The same route when covered under exactly similar conditions, except that conventional drive is used, gives vacuum readings of 7 inches and no ping. With overdrive the tachometer indicated engine revolutions per minute just within the economical speed range of the engine as determined by the designers, while with conventional gear ratio the engine revolutions per minute were practically in the center of that range.

Until the advent of the fluid power transmission devices, automatic overdrive was a popular adjunct and the driver of a car so equipped and covering this same route would, more than likely, have the overdrive in service. Upon leaving the main Foothill Boulevard at La Canada he would find that, in spite of the sharper grade, satisfactory speed could be maintained simply by using greater throttle opening. He would, however, be acutely conscious of the engine knock. If there is anyone who thinks that he would give any consideration to the thought that he was abusing his engine by using the overdrive gear ratio under the stated conditions, that person does not know the average automobile driver. The driver's only reaction would be the conviction that the gasoline in his tank was of inferior quality. The simplest and most effective answer to his complaint is the advice to use Ethyl gasoline. Tests with Ethyl gasoline over the same route and under identical conditions showed slightly improved vacuum and absence of ping, but exhaust gas readings were practically the same as with regular gasoline. This does not alter the fact that he is still wasting gasoline and abusing his engine by operating until a low engine revolutions per minute. When in overdrive the analyzer held around 8½ to 1 while; when operating in conventional, the mixture leaned off to approximately 12½ to 1. This differential was closely reflected in the gasoline mileage, some 17 percent better in conventional.

All of the foregoing is well known to automotive engineers and all of it could be made clear to the average person, but such discussion is outside the expressed scope of this article. We are hoping only to demonstrate that, as long as automotive vehicles are designed as they are and built as well as they are, there is little chance of developing a satisfactory measure of gasoline performance which can account for even a small part of the vagaries of their drivers.

The Standard Octane Scales

After much travail, certain methods have become more or less standard for measuring the probable knocking tendency of gasoline. Each of the methods is designed to a specific objective and, so long as these objectives are kept in mind, the present methods serve the purposes for which they are intended. When use of them is made, however, for commercial purposes the results are never satisfactory. While each method is different in details of determination the fundamental principle or measure is the same and, while most refinery men are familiar with the principle and the procedure, a restatement is in order.

The octane number of a motor gasoline is determined by matching it against a mixture of materials called reference fuels which have characteristics essentially identical with the pure hydrocarbons, heptane and iso-octane. The matching is done in a special test engine under specified test conditions and is carried on until a mixture of the reference fuels is found which produce the same degree of knocking in the engine as the gasoline being tested. The octane number of the gasoline is, then, the percent of iso-octane equivalent in the pseudo iso-octane-heptane mixture. For example, a gasoline rating 65 octane number is equivalent in its knocking characteristics to a mixture of 65 percent iso-octane and 35 percent normal heptane. Thus, by definition, normal heptane has an octane number of zero and iso-octane has an octane number of 100. It is pertinent to remark, at this point, that the current headache of the experts in this procedure is to devise a method which will accurately measure the octane number of some of the newer aviation fuels which actually exceed iso-octane in resistance to knock.

The ASTM method, D-357-39, is the standard method of the American Society for Testing Materials and, in the opinion of the writer, is the only method which should be used by anyone except technicians. It was adopted as standard in 1939, although it had been used as a tentative standard since 1933. Prior to that time it was known as the CFR Motor method and was based on the results obtained by the CFR Committee in the summer of 1932 during five weeks of cooperative road tests at Uniontown Mountain, Pennsylvania, and was followed by weeks of laboratory tests at the Waukesha Motor Company.

The CFR Research method (1939) was developed by the CFR (Consolidated Fuel Research) committee primarily for research purposes and was adopted in its present form in 1940. It is an outgrowth of the old research method developed during the early days of knock testing and was used as the standard knock-test method for nearly two years prior to the adoption of the CFR Motor method in 1932. For simplicity, the term research is generally used. As has been previously stated, the method has no general commercial application and is used by technical men as a measure of the proportion of unsaturates, particularly of the aromatic and olefinic types, in the gasoline.

In general, each method gives a different octane value for a given fuel, but there is no constant difference between the two methods for all types of fuels. With few exceptions, the Research method gives the higher ratings. The following octane numbers on three types of gasoline—(1) a typical leaded blend of straight-run and cracked, (2) a non-leaded cracked, and (3) a highly leaded straight-run—illustrate the results obtained by the two laboratory test methods.

FUEL No.	METHOD	
	ASTM	Research
1	75	80
2	73	81
3	78	78

Aviation gasolines for aspirated engines are rated in the laboratory by the 1-C method which has been adopted as a standard for this purpose by ASTM. An additional test method, known as the 3-C method, has since been brought out and has come into use for testing gasoline intended for use in supercharged engines. The conditions of the latter method are to be regarded as not for general publication for reasons of military security. The operating conditions of the

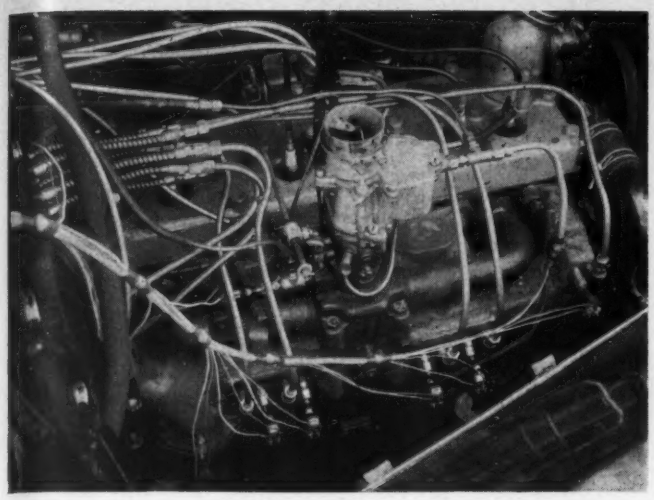


FIGURE 1
Where some of the readings originate

other laboratory knock rating methods are as follows:

	METHOD		
	ASTM	Research	1-C
Engine speed, rpm	900	600	1200
Mixture temp., °F.	300	125	220
Coolant temp., °F.	212	212	374
Spark advance, deg. btc	20	13*	35*
Method of measuring knock intensity	Bouncing pin	....	Temp. plug

* Fixed, not varied with compression ratio.

Effect of Initial Octane Number

Figure 5 shows how lead response is affected by the bare octane number of any stock. The graphs are entirely relative but can be used for comparison between any two or more stocks by using the lead susceptibility slope numbers on the right vertical line or making additional numbers as required, by projecting intersecting lines between octane numbers as determined by laboratory test. Do not, however, place too much stress on this valuation alone, for developments in catalytic cracking, superfractionation, alkylation and more accurate blending during the past few years have rather overshadowed the importance of initial octane number in evaluating a base stock for lead susceptibility.

Just a glance at the following table will indicate the force of the last statement.

	ASTM Octane Number
Iso butane	100
Normal butane	92
Iso pentane	91
Normal pentane	64

The Combined Effects

Figure 6 gives the complete results of a series of tests which have recently been completed. The entire project had certain definite objectives and was not originally intended for any purposes other than our own, but the results seemed so outstanding that it was decided to make them available to the refining industry. It should be noted that the gasolines were all from straight-run distillation and mild thermal cracking of Long Beach Harbor crude of approximately 26 API gravity.

The results of other investigations are shown in succeeding graphs taken from a paper, "A Refiner's Viewpoint on Motor Fuel Quality," by Holaday and Happel of Socony-Vacuum Oil Company, and presented before S.A.E. annual meeting in 1942.

The objective of this article will have been entirely missed or, shall we say that satisfactory answers to so what? will not have been found, unless the graphs are discussed from the angle of each of the sub-titular functions. We realize that the proposition is extremely complicated since each of the functions is affected by one or more of the others, either as a deterrent or as an accelerator. The objective is certainly worthwhile and its attainment is a dual responsibility of the man who presents the discussion and the men who read it. The writer joins the editor in the hope that others will join in the discussion of the matter by articulating their voices of experience in the columns of THE PETROLEUM REFINER.

For any of the readers who have had steam power experience, conception of the rather complex problem will be simplified if it is compared with the job of taking indicator cards from a large, compound, condensing, Corliss steam engine and adjusting the valve motion of the engine from a study of successive cards. Anyone who may have been fortunate enough to have had this experience, either as a part of his college career, or in actual operating experience, will realize the similarity between the two jobs inasmuch as both, necessarily involve consideration of the effect of any changes made in any one or more items upon all the other details and, consequently, upon the whole.

Analysis of Stocks Derived from Certain California Crudes

It will be seen by study of Figure 6 that these tests are not altogether complete but they were adequate for our needs at the time the study was made. It is suggested that other investigators may have covered stocks, blends and specifications of wider range and could, therefore, add materially to the general knowledge of the subject by submitting their results. Since our objectives were concrete, rather than abstract, we wasted no time in running tests on stocks which were outside specification range for motor fuel. For example, if the stock did not meet volatility specification it was brought to proper front-end volatility by blending with it the required amount of natural gasoline of 21-22 R.V.P. which had an average ASTM octane number of 74. This relatively high octane number, it should be noted, is due, not only to certain inherent characteristics of the crude petroleum whence it came, but, further, because its rather high vapor

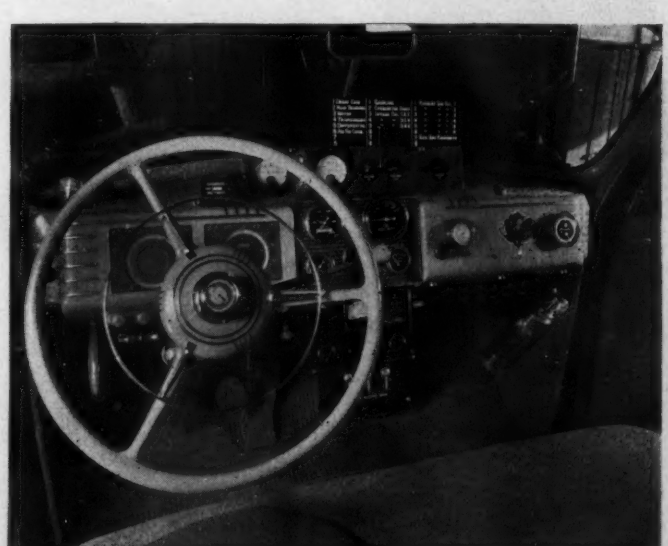


FIGURE 2
Cab and instrument panel of the Loping Laboratory

pressure indicates a considerable proportion of iso butane of 100 octane number.

Stocks Nos. 4 and 2 are base stocks except for the natural gasoline added for volatility correction. The natural gasoline runs very low in sulfur, which tends to reduce the total sulfur of the blend by dilution. No. 4, the straight-run material of 400 end point, received no chemical treatment other than a rather casual contact with clay. The natural gasoline required no treatment of any kind. After volatility correction the stock had a bare ASTM octane number of 68.8 which was increased 7½ numbers to 76.3 by addition of 1 cc. per gallon of tetraethyl lead. Note now how the angle of the curve undergoes change from 1 to 2 cc. per gallon, where the octane number rises only 4½ with the addition of another cubic centimeter of tetraethyl lead. Still further loss in lead response with the addition of a third cubic centimeter, gaining only 2½ numbers. From bare to allowable tetraethyl lead we have jumped the ASTM octane number 14.4 numbers and have demonstrated that, in spite of the rather high end point, we can produce a high-quality, regular-grade gasoline without expensive chemical treatment and with the use of only 0.5 cc. per gallon of tetraethyl lead from a full straight-run stock distilled from this particular crude. This is due to the low sulfur content of the fraction and certain other characteristics inherent with the crude of the limited area of the specified field. The same cut, when given 2 cc. of tetraethyl lead, shows a fairly good Ethyl gasoline and when the allowable is used the result is a markedly superior quality of Ethyl.

When the end point of the same stock is cut at 370 degrees, instead of 400 degrees, we find that the sulfur content has been cut nearly one half, even with a somewhat lower natural gasoline addition. In this connection, it may be said that the percentage of natural gasoline used was that necessary to bring a 10 percent point of about 140 degrees. When comparing the lower end point straight-run fraction with the No. 4, it should be noted that the bare octane number of the No. 2 stock is ½ number higher than the 400-end point fraction and that this differential is maintained almost uniformly on through to the 3 cc. concentration. It should also be observed that the Research method, which was run at 3 cc., is only 1.3 number ahead of the ASTM result. This is a characteristic of straight-run gasoline. It also seems difficult in face of these figures to justify cutting to the lower end point with its consequent loss in recovery; that is if the sulfur content can be held to a point below 0.10 percent.

Lead Response of Other Straight-Run Gasolines of Different Crude Sources and Varied Distillation Ranges

As has been previously pointed out, not all gasolines have equal tendencies to knock even when one or more of their specifications are equal. For example, a straight-run gasoline of given distillation range from some one particular field may have decidedly better anti-knock characteristics than one of identical boiling range and from a crude of perhaps the general classification as to gravity and type. A parallel of this condition is found in the lubricating oil cut from crude of different types and sources.

Nor are these variances equalized when either the heavier overheads or the residuals are cracked. In fact, even more differences develop and from different causes. In a generic sense, however, pressure distillates produced by, say, mild thermal cracking will show somewhat the same general bare octane number as well as equal lead susceptibility if other of their specifications are fairly close together. A comprehensive survey of all the curves shown with this article leads one to a safe, general conclusion; presence of branched chain and/or ring compounds together with very low sulfur content have a greater over-all effect of increasing bare octane number and bettering the

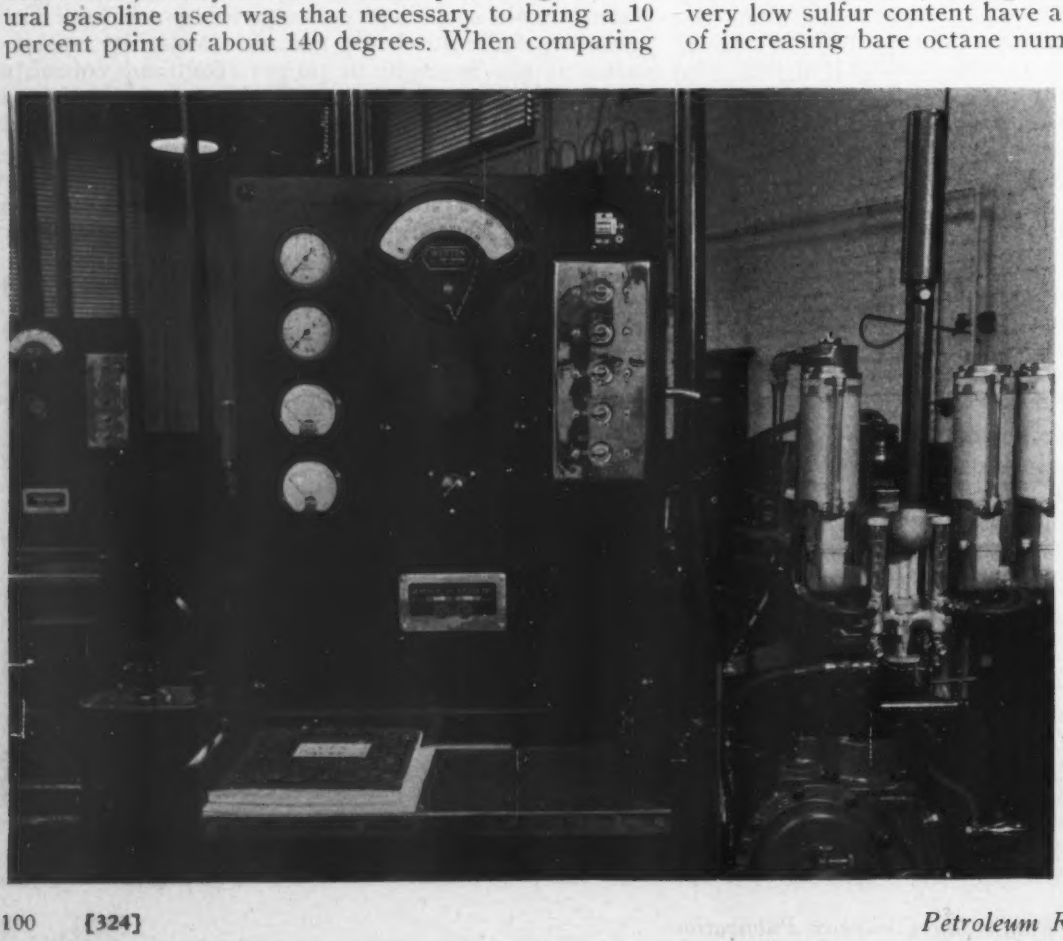


FIGURE 3
Standard CFR Knock Testing Engine for Motor Gasoline.

Courtesy Ethyl Corporation

lead response ability of the gasoline than any others of the characteristics.

For a comparison between straight-run gasolines from Long Beach Harbor field and from other fields refer to Figures 7 and 8. The comparison will show that, while naphthenic-base crudes generally produce straight-run gasolines of superior octane number and better lead susceptibility, the average is considerably below the results of our tests on the specific crude described. Figure 8 shows clearly the advantage of narrow boiling range, particularly in the low end points. It will be interesting to make a hypothetical equal-proportion blend of the three lowest boiling-range stocks shown and observe that the blend would have characteristics practically equal to those of the gasolines used in our Nos. 2 and 4 tests shown in Figure 6. Or, in practice, if the three fractions were combined in one tower overhead by refluxing, the result would be the same. A part of this seeming strange condition can be credited to better lead response due to low initial octane number and a part to the larger proportion of the iso or branched-chain compounds are found in the low-molecular-weight hydrocarbons. Note the effect of low initial octane number in the heaviest stock shown in Figure 8 by observing that the addition of 1 cc. of tetraethyl lead to it raised the octane number some 23 numbers, while the same amount of lead added to the lightest stock with highest initial octane number raised its octane rating only about 11 numbers, or less than half as much.

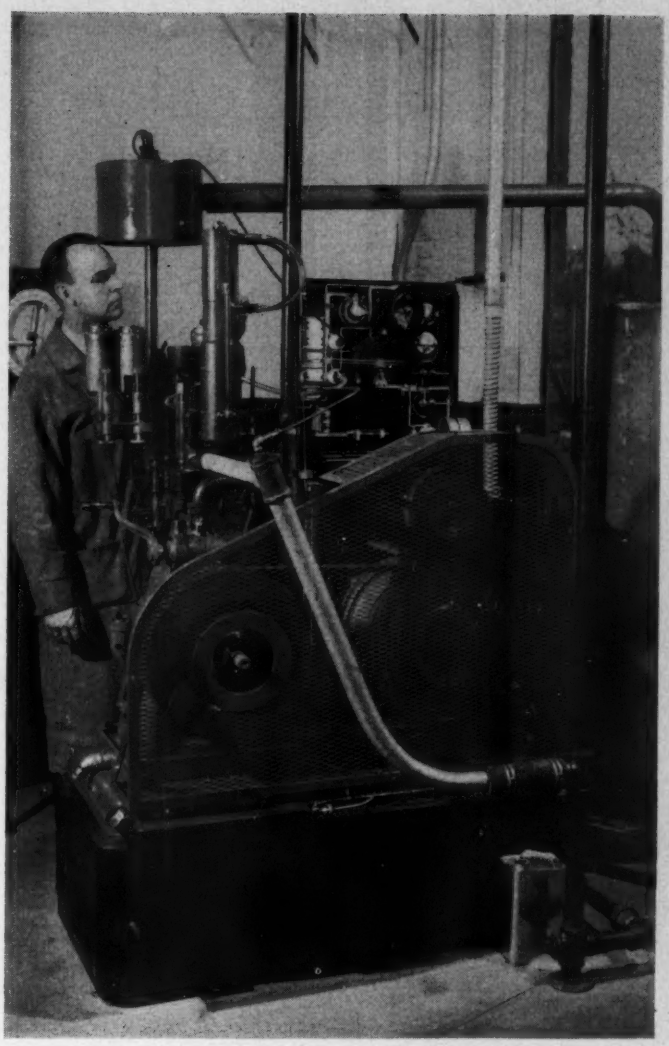
Study of Some Cracked Stocks

Study of results from stocks 3 and 5 in Figure 6 points out some interesting comparisons. Sulfur content is practically equal but the No. 3 sample had lower end point and had not required natural gasoline to bring its 10 percent into line. The ASTM octane number of the bare and lower end point material is seen to be 2½ numbers better than the 400-end point stock, but this spread drops to 1.3 numbers at a 1-cc. tetraethyl lead addition, 1.1 at 2 cc. and at full concentration there is but 0.3 numbers difference. The point here is that, while the lower end point was effective without tetraethyl lead, this advantage was overcome with increasing amount of lead, which conforms to the rule of better lead response with lower initial octane number.

It should now be interesting to observe the wide spread between the results shown by ASTM and Research methods when the stock is 100 percent cracked. The 400-end point stock, at 3 cc. per gallon showed, by the Research method, an improvement of 6.7 numbers, while the differential with the 370-end point material was 8.2 numbers. Straight-run stocks of same end point but with inherently low sulfur showed spreads between the two methods of only 1.3 and 0.9 respectively. Note also that even the slight spread between the two straight-run stocks under the ASTM method, disappeared entirely with the Research Method. The outstanding figure in the whole set of graphs is the remarkable showing, by the Research method, of the 370-end point cracked stock, the sulfur content of which had been reduced below 0.10 percent. *A Research octane number of 90 is not to be casually dismissed.*

Thermally Cracked Stocks from Other Sources

Figures 9 and 10 show results had with thermally cracked stocks from other sources, probably mixed base. No information is available on the sulfur content of these cuts. Figure 9 indicates that both the original ASTM octane number and the leaded responses are somewhat below the figures for the naphthenic-origin fractions. It should, however, be noted that, by the Research method, the 3 cc. response was better, probably due to the lower sulfur. Figure 10 serves to point up something which has heretofore been brought out by several investigators, that is; that end point is not as important a factor in controlling lead response of a cracked gasoline as it is of a straight-run. Obviously, if the lower three of these cuts were combined in one, the result would be a satisfactory Ethyl gasoline of perhaps 325 end point, which is somewhat higher with consequent better recovery than with straight-run gasoline from the same type of crude.



Courtesy Ethyl Corporation

FIGURE 4

CFR Knock Testing Engine with Ice Tower Humidity Control for Aviation Gasoline.

Response Ability of Blends of Straight-Run and Cracked Stocks

Since petroleum oils and gases are highly complex materials, composed as they are of perhaps hundreds of hydrocarbons and groupings thereof, many of which are of different molecular structure and chemical composition, it follows that efficient petroleum processing involves many different methods and the products of many of these processes must, inevitably, be blended with the products of some of the other processes to produce finished materials. Therefore,

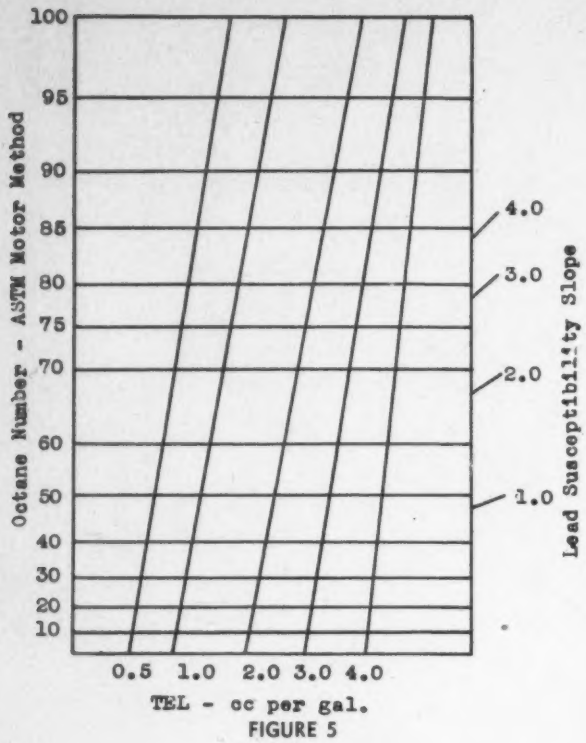


FIGURE 5

consideration must be given to this inevitability in any evaluation of the characteristics of the marketing blends.

We have seen how various characteristics of both straight-run and thermally cracked gasolines affect their ability to resist knocking and ability to respond to addition of lead in varying amounts. Now let's examine the results when a blend of the two is subjected to tests. The sulfur content of one of the blends was reduced to a point which would result in a figure of 0.25 percent when blended with the low-sulfur straight-run and natural gasolines. The figure of 0.25 percent is more or less representative of regular motor fuels. For the other blend, sulfur was reduced to 0.65 percent.

Since, as has been stated, motor gasolines usually are blends, a graphic summation of the results of our tests is shown in Figure 11. This will bring out more clearly than any number of words the pertinence of the results. Values by Research method are omitted since they would add nothing of practical value to this part of the discussion. The chart is not a repetition of Figure 6 only inasmuch as the same values are used; its scale is larger in order that the desired points may be properly emphasized. The reader is reminded that all figures are from actual tests, but that they cannot safely be assumed for any other crude or other cracking conditions than those specified. The sole idea was to set up a standard for guidance in seeking answers to the so what? of the problem as it applies to one's own needs and conditions. In analyzing results obtained by extreme sulfur reduction the reader should know that the reductions were made by laboratory methods using alkylation-spent sulfuric acid and conventional neutralizing and sweetening processes and materials. The amounts of acid used per unit of stock treated are not given since they would only be misleading. For the extreme reductions the amounts used would not be economically justifiable under past conditions and with past methods.

Characteristics of the Blend When Low-Sulfur Cracked Stock Is Used

First, it should be observed how steep is the lead-response curve for the straight-run part of this blend. It has the lowest clear octane number but with 1 cc. of tetraethyl lead it has passed all others except the low sulfur blend, while at 2 and at 3 cc. it has gone higher than any of the others. Technically then, it is the best stock to use for the premium grade of gasoline. In fact, as has been previously pointed out, it would be the most economical for the regular grade from the angle of low tetraethyl lead requirement. But there is a pesky "iffie" gremlin which sings out that there is not enough of this grade of stock or enough of this type of crude from which to distill it. And that is that. Nor will the situation be changed completely with dimunition of military demands for 100-octane aviation gasoline. It is entirely true that some of the

Lead Response for Various Refinery Stocks

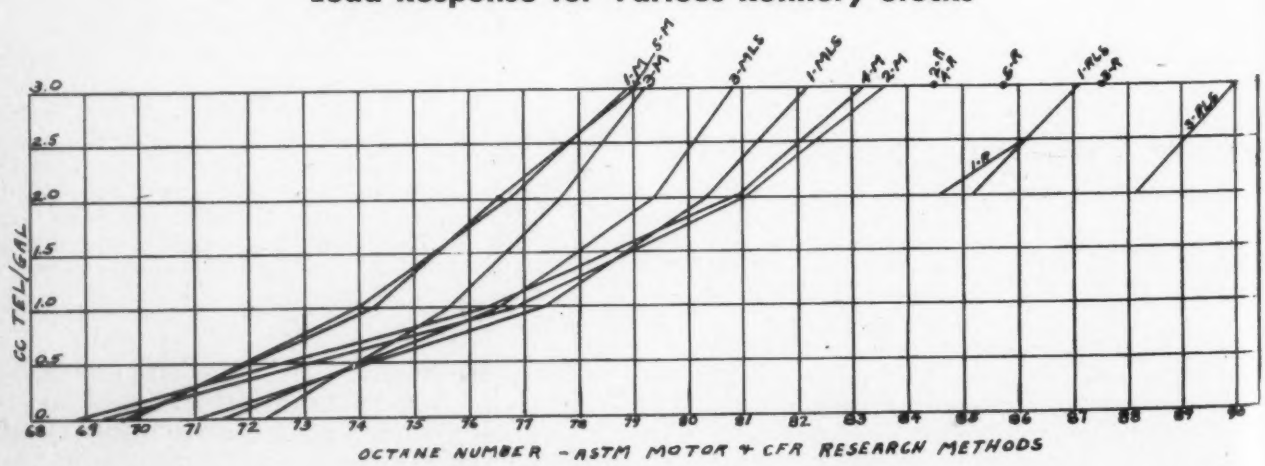


FIGURE 6

Legend:

M = ASTM Motor Method.

R = 1939 Research Method.

1 = 50 percent each cracked and S-R End point 370. Sulfur 0.25 percent.

1-LS = same except sulfur reduced to 0.065 percent.

2 = 100 percent S-R with 14 percent natural gasoline for volatility correction. Sulfur 0.04 percent. End point 370.

3 = 100 percent cracked. End point 370. Sulfur 0.36 percent.

3-LS = same except sulfur reduced to 0.075 percent.

4 = 100 percent S-R with 18 percent natural gasoline for volatility correction. Sulfur 0.07 percent. End point 370.

5 = 100 percent cracked with 10 percent natural gasoline for volatility correction. Sulfur 0.38 percent. End point 400.

products of alkylation, superfractionation, catalytic cracking and other processes will be available for motor gasoline after the war; but whatever these amounts are, everyone can be assured that none of it will be available for use in compounding a motor fuel of less than 90 octane number. Therefore, we shall still be faced with the problem of reducing sulfur of thermally cracked gasoline to such point that it can economically be used in gasoline of today's Ethyl specification.

When we blend this high-grade straight-run stock with cracked material of such sulfur content that the blend runs about 0.25 percent—which is the figure which has commonly been considered as acceptable—we end up with a gasoline with the lowest lead susceptibility of any of those tested. Rather expensive response ability, is it not?

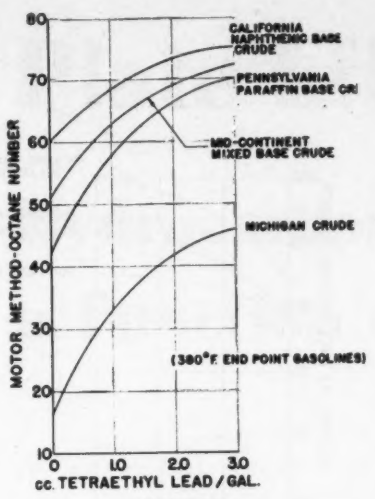


FIGURE 7

Octane numbers and tetraethyl lead susceptibilities, thermally cracked gasoline (400° F. end point gasoline from Mid-Continent crude.)

The writer feels that he has called attention to a sufficient number of detailed and obvious observations and now invites his readers to pick up the low-sulfur-blend curve and let each one see what he makes out of it. The results and implications are there, plainly to be seen, so that he who runs may read, but his reading will be of limited value if his vision is myopic.

The old order changeth. No refinery man can afford to dodge the clear implications of the definite trend toward higher standards of quality for motor fuel. Nor will he be doing any more than deluding himself by defining the trend as a temporary condition brought about by the demands of military aviation. Military necessity has forced us to do the things which have, heretofore, been considered as impracticable because of commercial necessity.

Catalytic cracking has played a very important part in producing this high-octane gasoline and will continue to do so, but it must be kept in mind that catalytic cracking is a highly selective process, as a result of which we shall have, in the form of rejects from the process, a very considerable amount of stock to be rerun by other processes. One of the important reasons for the high quality of the overhead from catalytic cracking is that the charge stock is selected with an eye to the economics of the process. It is well known that the high-octane product of catalytic cracking is very nearly sulfur-free, but this is not altogether due to the same type of catalytic reaction which brought about the high-octane rating of the product. Clay-type catalysts, chiefly by their adsorbent action, remove, or make innocuous, most of the sulfur compounds and undesirable polymers at the same time they are performing their primary function of molecular rearrangement. This adsorbent action, inevitably, contaminates the catalyst and it must be regenerated fre-

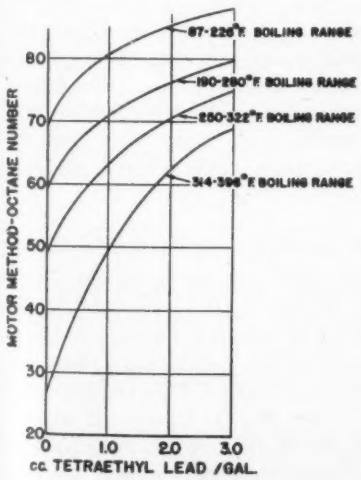


FIGURE 8

Octane numbers and tetraethyl lead susceptibilities. Narrow boiling fractions —straight run gasoline from Mid-Continent crude.

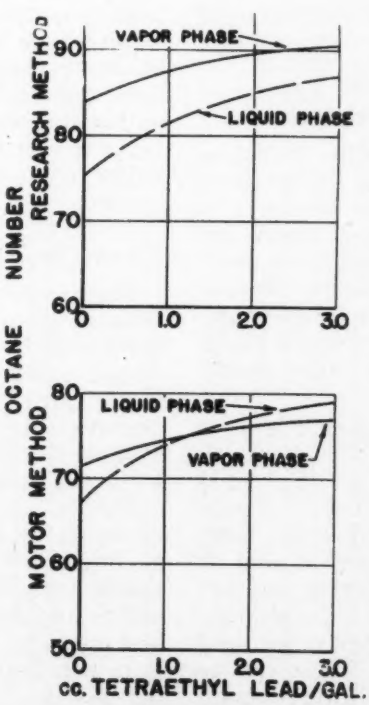


FIGURE 9

Octane numbers and tetraethyl lead susceptibilities—thermally cracked gasolines (400° F. end point gasoline from Mid-Continent gas oil.)

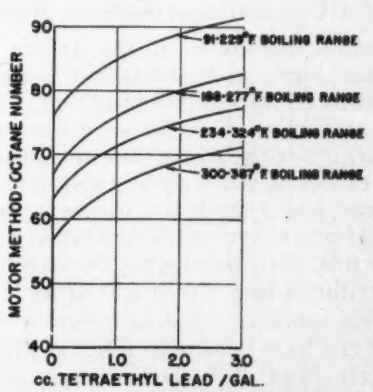


FIGURE 10

Octane numbers and tetraethyl lead susceptibilities. Narrow boiling fractions, thermally cracked gasoline (liquid phase East Texas residium charging stock.)

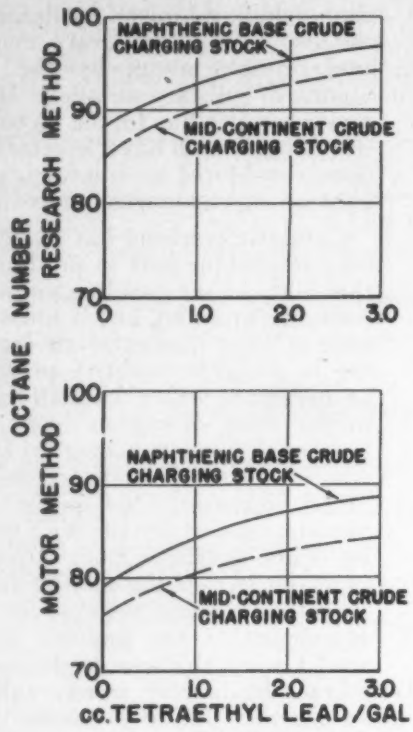


FIGURE 11

Octane numbers and tetraethyl lead susceptibilities — catalytically cracked gasolines.

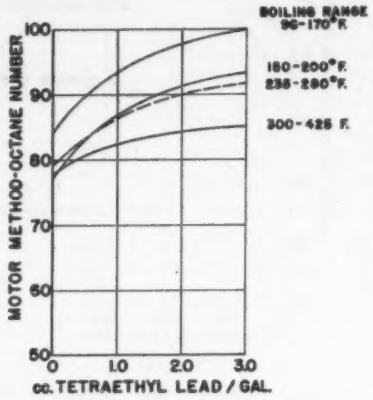


FIGURE 12

Octane numbers and tetraethyl lead susceptibilities, narrow boiling fractions, catalytically cracked gasoline.

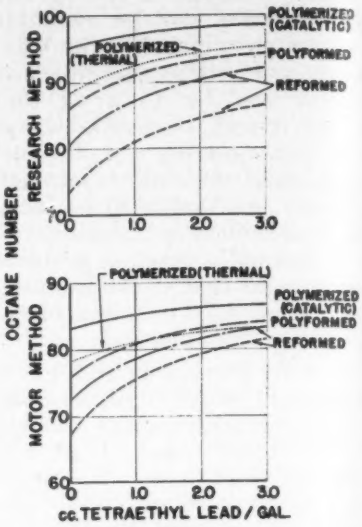


FIGURE 13

Octane numbers and tetraethyl lead susceptibilites — polymerized, reformed and polyformed gasolines.

quently. This is accomplished in several ways, but it will be obvious that the cycle of duty between regenerating cycles must be as long as is practicable else the amount of equipment required for regeneration would throw the economics of the process out of line. Hence the necessity for careful selection of charge stock and the conventional once-through operation.

Conventional Sulfuric Acid Treatment

One of the limits to the degree of sulfur reduction by sulphuric acid treatment which has always been considered as fundamental is the known tendency of the treatment to remove some of the desirable unsaturates at the same time the sulfur compounds were either being reduced or their form changed. This, of course, had a tendency to lower the bare octane number of a cracked stock and was considered as a factor which limited the degree by which total sulfur should be reduced in a motor gasoline.

The tendency can be seen by noting in Figure 6 that the bare octane number of the No. 3 stock of relatively high sulfur content is almost a full ASTM octane number better than the same stock of lower-than-0.10 percent sulfur. This condition reverses, however, at 0.5 cc. of tetraethyl lead per gallon, and so continues. The degree of loss of bare octane number by heavy sulfuric-acid treatment might be, and probably is, much more with stocks of other origin and cracked under more severe conditions. There can be no arbitrary general limit to which sulfur reduction should be carried. Each refiner can establish the limit for his particular conditions by careful weighing of costs against returns.

Sulfur reduction by catalysis has attained considerable prominence and has been found to be very effective on straight-run stocks. Gasolines treated by catalytic desulfurization should, generally, show no loss in clear octane number and, in fact, frequently show distinct improvement. For the present, at least, the logical field for this process would appear to be the reduction to a very low figure of the sulfur in the straight-run part of a blend, thereby increasing its diluent capacity. Catalytic desulfurization is not often used for cracked stocks because the thiophene type sulfur compounds seem to be unaffected by the process. It will be interesting to note that this type of sulfur compound has very little effect on lead response.

Lead Response of Catalytically Cracked Gasoline

Figures 11 and 12 show the susceptibility of "cat" cracked gasoline to lead, both by origin of charge stock and by distillation range. The increased clear octane number, as well as the better lead response and wider spread between ASTM and Research methods, are accounted for by the increased amount of branched-chain and aromatic compounds and by the sulfur and polymer reduction which has taken place coincidentally with the molecular rearrangement by catalysis. It should further be noted that, while recycling is not generally practiced in cat cracking, the gasoil formed and fractionated out of the product makes an excellent charge stock for thermal cracking and produces a gasoline on this rerun somewhat higher in anti-knock quality than a thermally cracked virgin gasoil.

Figure 13 demonstrates some lead susceptibilities of polymerized, polyformed and reformed gasolines. Analysis of these curves will be interesting and much the same principles will be found true as have hereinbefore been brought out.

Overall Plate Efficiency

Of Commercial Hydrocarbon Fractionating Columns as a Function of Viscosity

H. G. DRICKAMER and J. R. BRADFORD, Pan American Refining Corporation

CORRELATION between viscosity and plate efficiency has been developed from test data on 54 refinery fractionating columns. The curve was checked from data on 30 commercial columns obtained from the literature. The effect of variations in tray design was considered. Applications of the correlation to industrial operation are presented.

This paper was presented before the meeting of the American Institute of Chemical Engineers in New York, May 10 and 11, 1943, and printed in its Transactions 39, 3, June 25, 1943.

THE plate efficiency of fractionating columns is a function of tray design, column load, temperature and pressure of operation, and physical properties of the material being fractionated. However, for any group of columns having similar tray design and operated near maximum capacity, the overall tray efficiency is primarily a function of the physical properties of the material fractionated at the column temperature and pressure. In petroleum work, stabilizers, debutanizers, butane depropanizers, deisobutanizers, naphtha fractionators, and similar columns come under the above classification, and, in most cases, bubble-tray absorbers and strippers may also be considered in the same category.

The plate efficiency is, undoubtedly not a simple function of any one physical property, however, it was felt by the authors that a simple, usable correlation could be developed between some fundamental property and plate efficiency. It must be kept in mind that the authors were seeking, not a theoretically derived equation for tray efficiency as a function of some physical property, but merely a property or combination of properties whose variations are consistent with variations in tray efficiency. Naturally it is desirable to conform as closely to theo-

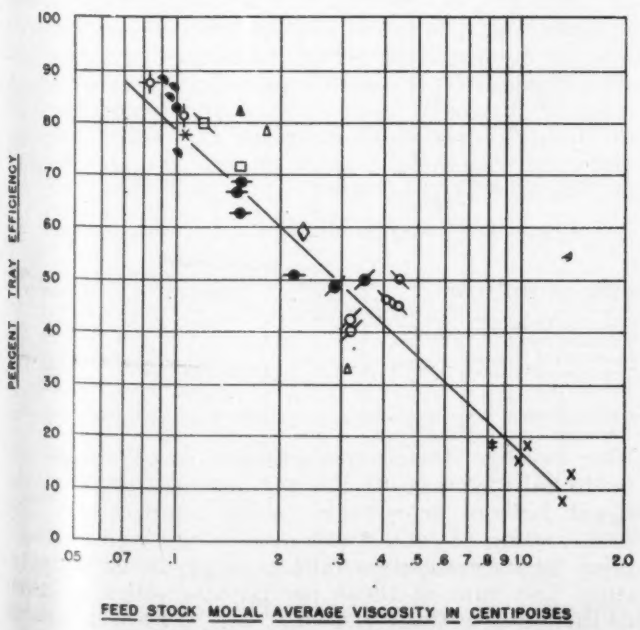


FIGURE 1A

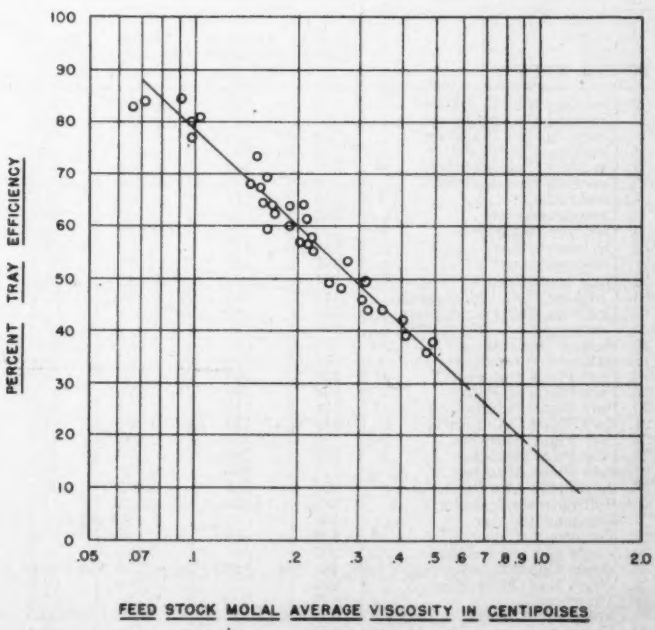


FIGURE 1B

retical considerations as a simple equation will permit.

Viscosity was selected as the determining physical property for several reasons.

First, the Stokes-Einstein equation for molecular diffusity

$$D = \frac{KT}{6\pi\tau\mu}$$

presents diffusivity as an inverse function of viscosity.

Second, the mass transfer equation of Chilton and Colburn[10]

$$K = \frac{Gm}{Mm}\left(\frac{\rho k_d}{\mu}\right)^{.67} j$$

denotes turbulent mass transfer as an inverse function of viscosity.

Third, the von Karman[32] equation for film thickness

$$y = \frac{(\text{constant})\mu}{G\left(\frac{f}{2}\right)}$$

indicates that film thickness is directly related to viscosity. The mass transfer is an inverse function of the length of the path, i.e., the thickness of the liquid and vapor films. Since, for the temperatures and molecular weights under consideration, the viscosities of liquid hydrocarbons are 10 to 100 times the viscosities of corresponding vapor hydrocarbons, and further, the rate of change of liquid viscosity with temperature and with molecular weight is 2 to 15 times the rate of change of vapor viscosity, relative liquid viscosity makes the better criterion of film thickness and therefore of relative mass transfer rate and overall tray efficiency.

Fourth, the equation for liquid mass transfer coefficient

$$K_{1a} = \frac{3.4}{(\mu)^{.58}}$$

developed from experimental data by Sherwood and Walter,[30] again indicates an inverse relationship between mass transfer rate and viscosity.

Since a preliminary correlation between K_{1a} and tray efficiency was quite successful, an inverse relationship between tray efficiency and viscosity was postulated.

Table 1 presents the results of calculations on tests made on various towers at the Texas City refinery of Pan American Refining Corporation. Figure 1A shows these same results in graphical form. A large part of the data obtained in these tests may be found in Section 1 at the end of the article.

TABLE 1

Source: Texas City Plant Test Data **Reference: Figure 1A**

TOWER TYPE	Aver. Temp. °F.	Average Pressure PSI Abs.	Molal Average Viscosity	Percent Tray Efficiency
1. Cracking Unit Stabilizer	312	357	0.066	83.0
2. Cracking Unit Stabilizer	315	347	0.072	84.0
3. Cracking Unit Stabilizer	313	366	0.091	84.2
4. Cracking Unit Stabilizer	314	350	0.098	80.0
5. Cracking Unit Stabilizer	319	363	0.105	81.0
6. Cracking Unit Stabilizer	309	363	0.098	77.0
7. Debutanizer*	275	117	0.165	59.0
8. Deisopentanizer*	280	116	0.160	64.0
9. Deisopentanizer*	270	116	0.172	62.0
10. Deisopentanizer	260	117	0.152	73.0
11. Deisopentanizer	262	116	0.158	67.7
12. Deisopentanizer	264	115	0.162	69.0
13. Cracking Unit Debutanizer	245	115	0.190	60.0
14. Cracking Unit Debutanizer	252	130	0.213	61.5
15. Cracking Unit Debutanizer	248	125	0.210	64.0
16. Butane Depropanizer	162	235	0.148	68.0
17. Butane Depropanizer	161	235	0.170	64.0
18. Poly Plant Stabilizer	228	365	0.220	58.0
19. Poly Plant Stabilizer	198	362	0.222	55.0
20. Poly Plant Debutanizer	238	145	0.310	46.0
21. Poly Plant Debutanizer	242	147	0.322	44.0
22. Poly Plant Absorber	126	255	0.405	42.0
23. Poly Plant Absorber	127	260	0.410	39.0
24. Poly Plant Absorber	124	265	0.500	38.0
25. Poly Plant Absorber	120	260	0.480	36.0
26. Hydroformer Stabilizer	285	350	0.355	44.0
27. Kerosene Stripper	448	68	0.205	57.0
28. Kerosene Stripper	435	68	0.190	64.0
29. Virgin Gas Oil Stripper	507	60	0.250	49.0
30. Virgin Gas Oil Stripper	481	58	0.270	48.0
31. Virgin Gas Oil Stripper	492	60	0.280	52.0
32. Absorber	138	267	0.220	56.4
33. Absorber	132	254	0.310	50.0
34. Absorber	117	94	1.410	10.4

* Bottom 11 trays perforated in tower.

Method of Calculation

For each test, the Podbielniak analyses were converted to a molal basis, and a material balance was made around the tower. For fractionating equipment, minimum reflux was calculated by the method presented by Colburn.[11] The minimum number of plates were determined in the manner recommended by Brown and Holcomb[2] (calculating one or two plates down from the top and one or two plates from the bottom, then applying Fenske's equation[13]). The number of theoretical plates required at the operating reflux ratio was obtained from the chart by Brown and Martin.[4] Several columns were also calculated by the method of Brown and Souders[6] and by plate to plate calculations with enthalpy balances on each plate. The results obtained by the various methods did not vary by more than a fraction of one theoretical plate. The absorber and stripper tray efficiencies were calculated by obtaining the necessary number of plates from the absorption and stripping factor chart,[6] using an effective absorption or stripping factor, and checking top and bottom temperatures by equilibrium and enthalpy balances. The method is substantially the one described by Edmister.[12] The equilibrium constants used in both fractionator and absorber calculations were calculated from fugacity data by Sherwood.[28]

Correlation of Results

The plate efficiencies were plotted against the molal average viscosities of the feed, or, in the case of absorbers, of the rich oil, at the average tower temperature. The molal average viscosity of the feed was selected because, while it has no direct physical significance, it is the most representative value which is easily obtainable in ordinary design work. Further, for light hydrocarbon mixtures the molal average viscosity seems quite close to the actual viscosity as indicated by these data.

TYPE OF MIXTURE	Calculated (Molal Average) Viscosity	Experimental Viscosity
Stabilized Gasoline	.125	.118
Stabilized Gasoline	.110	.123
Debutanized Gasoline	.184	.190
Debutanized Gasoline	.210	.198
180°-340° Cut	.265	.270

The average tower temperature is taken as the arithmetic average of the top temperature and the tower bottom or reboiler outlet temperature. The mol fraction of each component in the feed is multiplied by its viscosity at the average tower temperature. The sum of these partial viscosities is taken as the molal average viscosity. E.g., for a fractionator having an average temperature of 190° F., the plate efficiency is obtained in the following manner:

TABLE 1

COMPONENT	Mol Fraction	μ 190° F.	Mf.x.μ
C_3	0.2	0.048	0.0096
C_4	0.3	0.112	0.0336
C_5	0.2	0.145	0.0290
C_6	0.3	0.188	0.0564

The molal average viscosity of the feed is relatively easy to obtain since most methods of fractionating-tower design require calculation of top and bottom temperatures and the feed composition is generally known. Figures 2A and 2B present available viscosity data [18, 19, 20, 24, 25, 33] for many hydrocarbon compounds.

The proposed plate efficiency of fractionating equipment may be obtained from Figure 1A or may be calculated from the equation:

$$E = 0.17 - 0.616 \log_{10} (\Sigma M\mu)$$

where

E = plate efficiency (ratio of theoretical to actual plates)

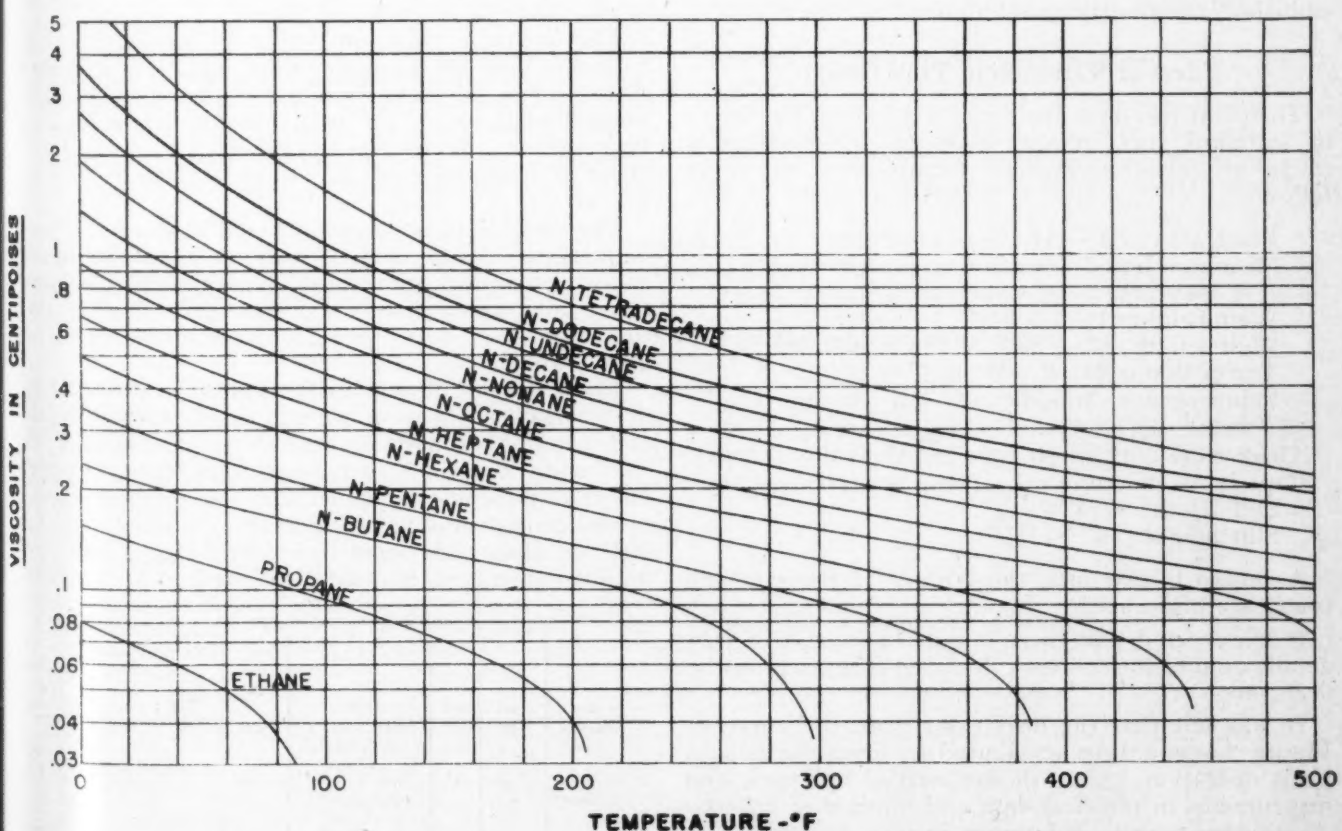
This equation, as derived from the above mentioned curve, appears valid for viscosity readings between the limits of 0.07 and 1.4 centipoises.

Literature Data

Table 2 presents results obtained on petroleum fractionating columns available in literature data. In Figure 1B the plate efficiencies of these columns are plotted on the curve obtained from Figure 1A. Where possible, the plate efficiencies were calculated by the methods described for plant test data; however, sufficient data were not always available. In general, the agreement of the literature points to the curve appears to be very good, and a valid explanation exists for the three points (indicated by the symbols △ and ▲) which materially disagree with the correlation. These three plate efficiencies were calculated for only a section of the tower and the compositions were obtained by breaking up true-boiling-point curves into normal paraffin components. The theoretical plates were calculated by a modified plate-to-plate calculation. Since no feed stream existed for these sections of towers, the average composition of liquid leaving the bottom plate and vapor leaving the top plate was used to obtain the molal average viscosity. However, in the case of the naphtha fractionator presented by Brown, et al.,[5] the calculated overall plate efficiency for the entire column is in line with the value taken from the curve.

Application to Water-Organic Liquid Mixtures

Table 3 lists four points obtained for commercial data on beer stills, alcohol-water columns, and an acetic acid-water column. While these points, as plotted on Figure 1B, show remarkable agreement with the correlation, the authors do not claim that this or any similar curve will necessarily apply to columns fractionating mixtures of water and miscible organic liquids. The data were presented as a matter of interest and it is hoped that someone with the



NOTE: OLEFINS ARE APPROXIMATELY 15% MORE THAN THE CORRESPONDING PARAFFIN HYDROCARBON.

BRANCHED CHAIN HYDROCARBONS ARE APPROXIMATELY 10% LESS THAN THE CORRESPONDING NORMAL HYDROCARBON.

FIGURE 2A

	Source of Data	Symbol	Ref.	Tower Type	Avg. Tower Temp. ° F	Avg. Pressure Psi-Abs.	Molal Avg. Viscosity	% Tray Efficiency
1	Atkins and Franklin		1	Absorber	101	78	0.81	18.0
2	Brown and Holcomb		2	Natural Gasoline Stabilizer	198	215	0.105	82.6
3	Brown and Lockhart		3	Gasoline Fractionator	197	200	0.100	74.0
4	Brown and Lockhart		3	Gasoline Fractionator	217	250	0.09	88.0
5	Brown and Lockhart		3	Gasoline Fractionator	200	203	0.097	86.0
6	Brown and Lockhart		3	Gasoline Fractionator	205	208	0.095	83.0
7	Brown, Singer and Wilson		5	Naphtha Fractionator	420	14.7	0.23	59.0
8	Brown, Singer and Wilson		5	†NaphthaFract. (first 6 plates)	375	14.7	*0.181	78.0
9	Brown, Singer and Wilson		5	†Naphtha Fract. (last 6 plates)	465	14.7	*0.315	33.0
10	Brown and Souders		7	Absorber	103	485	0.40	46.0
11	Brown and Souders		7	Absorber	93	485	0.42	45.0
12	Brown and Souders		7	Absorber	100	60	0.42	50.0
13	Brown, Souders, Nyland & Hesler		8	‡Natural Gasoline Stabilizer	260	300	0.085	88.0
14	Burdick		9	Natural Gasoline Stabilizer	193	188	0.106	78.0
15	Gunness		16	Natural Gasoline Stabilizer	196	265	0.102	83.0
16	Lewis and Wilde		21	†Naphtha Fract. (first 6 plates)	370	14.7	*0.154	82.0
17	McGiffin		22	Naphtha Fract. (Test #I)	240	135	0.151	63.0
18	McGiffin		22	Naphtha Fract. (Test #II)	236	125	0.156	69.0
19	McGiffin		22	Naphtha Fract. (Test #III)	214	125	0.152	67.4
20	McGiffin		22	Naphtha Fract. (Test #IV)	157	110	0.22	51.0
21	Nelson		23	Natural Gasoline Stabilizer	215	95	0.154	72.0
22	Sherwood and Jackson		29	Absorber	66	92	1.44	8.7
23	Sherwood and Jackson		29	Absorber	60	92	1.58	13.0
24	Sherwood and Jackson		29	Absorber	100	87	1.02	18.4
25	Sherwood and Jackson		29	Absorber	108	87	0.97	15.6
26	Turner and Rubey		31	Deisobutanizer	154	120	0.120	80.5

* Taken as molal average viscosity of liquid leaving the top and bottom plates of the section.
† All analyses taken from a split-up of true boiling point curves.
† Taken on plates below the side drawoff.

TABLE 2

necessary information available will check the possibilities of a similar correlation.

Effect of Variation in Tray Design

The plant test data presented were taken on towers of standard tray design, however, a considerable range of variation in tray details was noted, as follows:

Riser area: 7.2 — 11.5% of tray area
Minimum liquid downflow area: 4.5 — 9.9% of tray area
Weir height: 1½" — 2¾"
Weir length: 65 — 80% of tower diameter
Tower diameter: 4' — 0" to 7' — 6"
Submergence (middle of slot to top of weir): ⅞" — 2⅛"

There were both single pass and double pass trays.
Caps in all columns except one were rectangular:
Slot width: 3/32" — ¼"
Slot height: ¾" — 1¼"

As noted in the data, the bottom 11 trays in one tower are perforated.

It is expected that there is much variation in tray details among the towers calculated from data in the literature.

It was felt that the deviations from the curve in Figure 1A could be attributed to irregularities in plant operation, errors in commercial analyses, and inaccuracies in physical data and method of calculation, rather than to differences in tray design.

To prove this hypothesis, the results of ten tests on each of two commercial columns are presented in Table 4. (Data presented in Section II at end of paper.) As can be seen from the table, the charge rate and composition, and reflux rate were kept fairly constant (20 percent maximum variation) within the range of normal operation.

The average plate efficiency as predicted from Figure 1A or the corresponding equation, are very close to the calculated results. However, the maximum deviations for the two columns are at least as large as any deviations in Figure 1A, and of the order of magnitude of the larger deviations of Figure 1B.

The small variations encountered in standard commercial tray design evidently do not effect the liquid-vapor contacting appreciably under normal column liquid and vapor loads. Furthermore, small variations in tower load seem to have little effect on plate efficiency.

These results do not imply that an improved tray design will not permit an increased normal liquid and vapor load with no loss in tray efficiency, or that wide variations in column load have no effect on tray efficiency. However, the low efficiencies obtained on columns handling viscous liquids, particularly on absorbers, seem to indicate that a standard bubble-cap tray is not the ideal method for contact-

	Source	Symbol	Ref.	Tower Type	Avg. Tower Temp. ° F.	Avg. Pressure Psi-Abs.	Molal Avg. Viscosity	Per Cent Tray Efficiency
1	Gunness-Baker		17	Beer Stills (Perforated Trays)	208	16	0.32	41.0
2	Gunness-Baker		17	Beer Stills (Perforated Trays)	210	17	0.32	42.5
3	Peters		26	Acetic Acid-Water Tower (Sieve Trays)	218	15	0.35	50.0
4.	Peters Robinson		26 27	*Alcohol-Water Tower	200	15	0.29	49.0

* Average of 5 tests on commercial columns with sieve trays.

TABLE 3

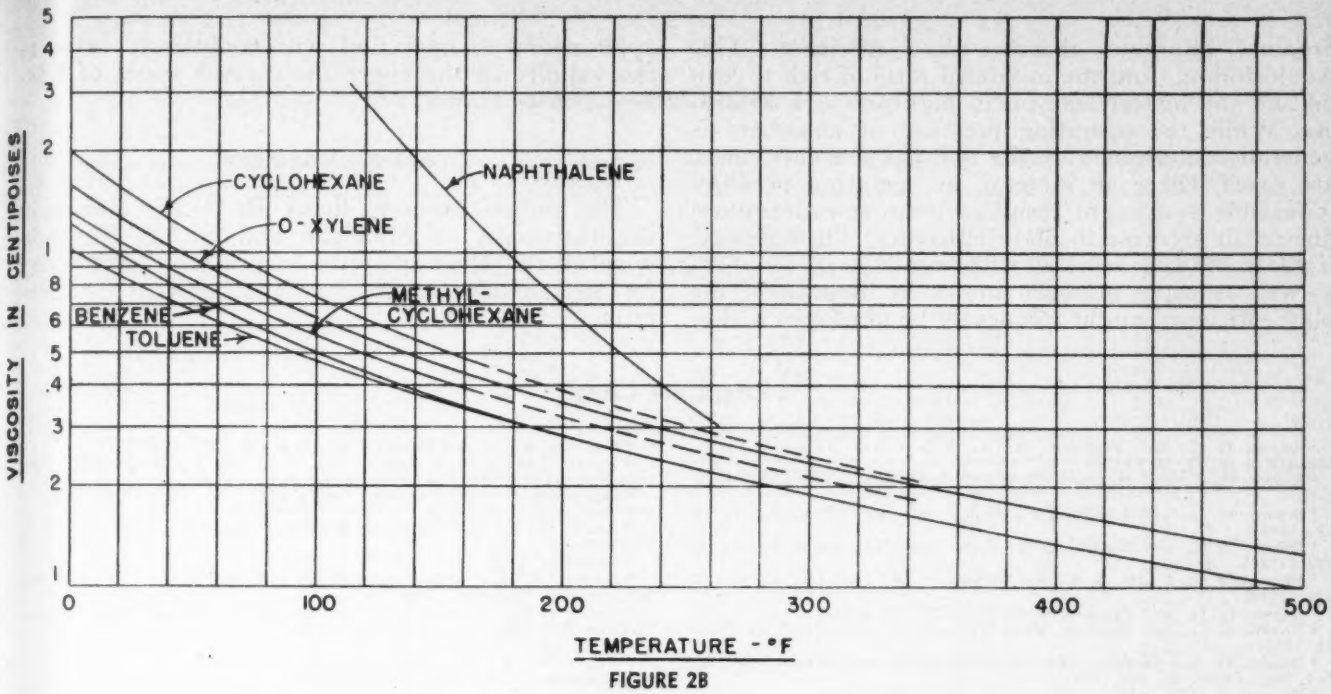


FIGURE 2B

ing a viscous liquid and a vapor. Methods of contacting which emphasize breaking up the liquid rather than the vapor, would possibly improve the efficiency of absorption operations.

Summary

Petroleum fractionating equipment of all types indicate a close correlation on the basis of overall plate efficiency. In the case of absorbers, difficulty was sometimes encountered in obtaining similar plate efficiencies for different components in the same test. This may be due to the solubility effect described by Sherwood and Walter[30] or to the difficulty in obtaining accurate equilibrium constant values for lean oil-gas mixtures. The efficiencies used were those of the key components, usually butane and pentane.

Within the limits mentioned in the first paragraph, i.e., (1) where a column is operated near capacity, and (2) with ordinary tray design, such that the factors of submergence, by-passing, entrainment, and flooding may be ignored, the correlation permits a rapid and useful determination of the tray efficiency of refinery fractionating equipment.

Applications in Industry

The primary application of the correlation is to process design calculations, however, the curve may be useful in improving operating conditions as well. For instance, it is apparent from the data that high

TABLE 4
Fractionating

	COLUMN I Key Components: Isobutane-Normal Butane									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Mols Feed	1801.3	1887.9	1819.2	1971.1	1839.7	1810.7	2055.8	1718.2	1684.2	1734.3
Mols Overhead Product	512.4	520.5	453.2	499.8	457.2	546.2	504.1	443.8	425.7	433.5
Mols Bottom Product	1288.9	1367.4	1366.0	1471.3	1381.5	1264.5	1551.7	1274.4	1258.6	1300.8
Mols External Reflux	2075.0	2160.0	2180.0	2310.0	2130.0	2040.0	2445.0	2005.0	1980.0	2055.0
Average Tower Temperature—°F	307	303	302	304	304	304	305	302	303	303
Molal Average Viscosity of Feed (at average tower temperature)	0.102	0.112	0.114	0.116	0.107	0.107	0.112	0.116	0.115	0.116
Efficiency Predicted from Fig. 1A	77.8	75.5	75.1	74.7	77.0	77.0	74.5	74.7	75.0	74.6
Calculated Efficiency	76.0	75.0	79.0	75.0	83.0	81.5	74.5	77.0	73.0	73.5
Theoretical Plates from Fig 1A	12.5	12.1	12.0	11.95	12.1	12.3	11.9	11.95	12.0	11.95
Theoretical Plates—Calculated	12.2	12.0	12.7	12.0	12.3	13.1	11.9	12.3	11.7	11.8
Difference	+.3	+.1	—.7	—.05	—.2	—.8	0	—.35	+.3	+.15

Average Efficiency from Figure 1A (for the 10 tests) =75.6% Average Calculated Efficiency (for the 10 tests) =76.7%

	COLUMN II Key Components: Isopentane-Normal Pentane									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Mols Feed	1288.9	1367.0	1366.0	1471.3	1381.5	1264.5	1551.7	1274.4	1258.6	1300.8
Mols Overhead Product	221.3	272.3	252.9	268.4	248.1	236.5	275.3	222.2	238.3	268.6
Mols Bottom Product	1067.6	1094.7	1113.1	1202.9	1133.5	1028.0	1276.4	1052.2	1020.3	1032.2
Mols External Reflux	1091.0	1161.0	1110.0	1119.0	1090.0	1065.0	1071.0	1059.0	1162.0	1031.0
Average Tower Temperature—° F	244	251	254	252	253	252	254	254	256	254
Molal Average Viscosity of Feed (at average tower temperature)	0.184	0.186	0.193	0.191	0.196	0.195	0.198	0.200	0.198	0.199
Efficiency Predicted from Fig. 1A	62.1	62.0	61.0	61.2	60.6	60.7	60.5	60.1	60.5	60.3
Calculated Efficiency	59.0	56.0	57.0	61.5	61.0	61.0	66.5	62.5	58.0	57.5
Theoretical Plates from Fig. 1A	16.8	16.75	16.5	16.55	16.4	16.4	16.35	16.2	16.35	16.3
Theoretical Plates—Calculated	15.9	15.2	15.4	16.6	16.5	16.5	17.7	16.9	15.7	15.5
Difference	+.9	+1.55	+1.1	—.05	—.1	—.1	—1.35	—.7	+.65	+.8

Average Efficiency from Figure 1A (for the 10 tests) =59.5% Average Calculated Efficiency (for the 10 tests) =58.5%

pressure improves absorber-plate efficiency. This would follow from the increased ratio of rich to lean oil and the lighter lean oil in high-pressure absorbers. While the operating pressure of absorbers is generally determined by the rich gas pressure, there are cases where an increase in operating pressure is feasible and might result in improved absorption due to an increase in plate efficiency. Furthermore, if a lean oil were selected with regard to its viscosity as well as vapor pressure and other limitations, the plate efficiency might frequently be improved. Other applications to operation will doubtlessly arise as the validity of the curve for various types of fractionation is shown.

Acknowledgment

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DATA—SECTION I

TOWER	Absorber
Number of Plates	24
Plate Spacing	18″
Tower Diameter	4′–0″
Tower Pressure	236 psi gage
Lean Oil Temperature	97 °F.
Rich Oil Temperature	127 °F.
Rich Gas Temperature	126 °F.
Lean Gas Temperature	127 °F.
Lean Oil Rate	1,520 BPD
Rich Oil Rate	2,180 BPD
Rich Gas Rate	15,170 MCF/Day
Lean Gas Rate	14,270 MCF/Day
Lean Oil Molecular Weight	206
Lean Oil Gravity	28 °API
Intercooler:	
Oil In	117 °F.
Oil Out	102 °F.

COMPOSITION	Rich Gas*	Lean Gas*	Rich Oil*	Lean Oil*
C_1	42.3	44.8	2.1	....
C_2=	7.1	6.7	6.1	....
C_2	23.0	23.0	12.1	....
C_3=	5.2	5.2	2.7	....
C_3	18.1	17.1	17.7	....
C_4=	0.8	0.6	2.0	....
C_4	2.4	2.2	2.9	....
C_5=	0.3	0.1	1.9	....
C_5	0.6	0.3	2.6	....
C_6+	0.2	....	40.0	100.0

TOWER	Absorber
Number of Plates	16
Plate Spacing	30″
Tower Diameter	5′–0″
Tower Pressure	244 psi gage
Lean Oil Temperature	95 °F.
Rich Oil Temperature	132 °F.
Rich Gas Temperature	97 °F.
Lean Gas Temperature	126 °F.
Lean Oil Rate	6,370 BPD
Rich Oil Rate	11,085 BPD
Rich Gas Rate	21,712 MCF/Day
Lean Gas Rate	15,170 MCF/Day
Lean Oil Gravity	57.4 °API
Molecular Weight of C_6+ Fraction in Lean Oil	157
Molecular Weight of C_6+ Fraction in Rich Gas	110

COMPOSITION	Rich Gas*	Lean Gas*	Rich Oil*	Lean Oil*
C_1	30.9	42.3	2.8	0.8
C_2=	5.3	7.1	1.5	6.6
C_2	18.5	23.0	6.7	
C_3=	5.6	5.2	4.8	7.4
C_3	23.6	18.1	23.0	
C_4=	2.6	0.8	4.5	6.9
C_4	8.1	2.4	14.8	
C_5=	0.8	0.3	2.5	8.1
C_5	4.0	0.2	2.3	
C_6+	4.0	0.2	37.1	70.2

TOWER	Deisopentanizer
Number of Plates	27
Plate Spacing	24″
Tower Diameter	6′–0″
Tower Pressure	101 psi gage
Tower Top Temperature	175 °F.
Tower Bottom Temperature	380 °F.
Feed Temperature	300 °F.
Feed Rate	13,200 BPD
Overhead Product Rate	3,880 BPD
Bottoms Product Rate	9,320 BPD
Pumpback Reflux Rate	8,640 BPD
C_6+ Molecular Weight	112
C_6+ Gravity	49.9 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_3	3.5	9.5	....
C_4	23.7	62.3	0.1
C_5=	5.9	10.2	3.5
iC_5	3.1	7.4	0.6
nC_5	6.2	10.6	3.7
C_6+	57.6	....	92.1

NOTE: Bottom 11 plates of tower perforated. Volatility of Butane cut equivalent to Butene —1.

TOWER	Absorber
Number of Plates	16
Plate Spacing	30″
Tower Diameter	5′–0″
Tower Pressure	251 psi gage
Lean Oil Temperature	87 °F.
Rich Oil Temperature	130 °F.
Rich Gas Temperature	93 °F.
Lean Gas Temperature	116 °F.
Lean Oil Rate	5,440 BPD
Rich Oil Rate	14,846 BPD
Rich Gas Rate	26,200 MCF/Day
Lean Gas Rate	13,450 MCF/Day
Molecular Weight of C_6+ Fraction in Lean Oil	164
Gravity of C_6+ Fraction in Lean Oil	41.7 °API
Molecular Weight of C_6+ Fraction in Rich Oil	110

COMPOSITION	Rich Gas*	Lean Gas*	Rich Oil*	Lean Oil*
C_1	27.7	50.2	3.1	1.1
C_2=	3.9	6.1	1.6	6.7
C_2	17.3	23.9	9.0	
C_3=	3.8	2.7	3.8	2.1
C_3	19.4	12.2	20.8	
C_4=	3.0	0.5	4.5	6.7
C_4	16.0	2.7	24.0	
C_5=	0.4	0.4	0.4	11.9
C_5	1.9	1.1	4.5	
C_6+	6.6	0.2	27.9	71.5

TOWER	Absorber
Number of Plates	16
Plate Spacing	24″
Tower Diameter	4′–0″
Tower Pressure	79 psi gage
Lean Oil Temperature	102 °F.
Rich Oil Temperature	126 °F.
Rich Gas Temperature	108 °F.
Lean Gas Temperature	108 °F.
Lean Oil Rate	368 Mol./hr.
Rich Oil Rate	525.4 Mol./hr.
Rich Gas Rate	946 Mol./hr.
Lean Gas Rate	786.9 Mol./hr.
Lean Oil Molecular Weight	250
Lean Oil Viscosity	1.4 centipoises at 116 °F. (34.5 S.U. at 100 °F.)
Lean Oil Gravity	21 °API

COMPOSITION	Rich Gas*	Lean Gas*	Rich Oil*	Lean Oi *
C_1	47.30	55.90	1.33	.....
C_2	8.80	9.80	1.16	.....
C_3=	5.20	5.14	1.66	.....
C_3	22.60	21.65	8.19	.....
C_4=	3.80	2.34	3.33	.....
C_4	7.40	4.45	6.66	.....
C_5	3.00	.72	4.01	.....
C_6	1.90	.....	3.42	.....
L O.	.....	.....	70.24	100

TOWER	Deisopentanizer
Number of Plates	27
Plate Spacing	24″
Tower Diameter	6′–0″
Tower Pressure	102 psi gage
Tower Top Temperature	165 °F.
Tower Bottom Temperature	380 °F.
Feed Temperature	300 °F.
Feed Rate	12,810 BPD
Overhead Product Rate	3,110 BPD
Bottoms Product Rate	9,700 BPD
Pumpback Reflux Rate	9,710 BPD
C_6+ Molecular Weight	118
C_6+ Gravity	49.7 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_3	1.3	6.4	....
C_4	16.6	71.6	0.4
C_5=	4.8	8.3	3.7
iC_5	3.5	9.0	1.6
nC_5	4.6	4.7	4.5
C_6+	69.2	....	89.8

NOTE: Bottom 11 plates of tower perforated. Volatility of Butane cut equivalent to Butene —1.

*Mol Percent.
†Liquid Volume Percent.
‡Mol percent from breakup of true-boiling-point curves.
All liquid quantities are in standard barrels (42 U. S. gallons) per day.
All vapor quantities are in thousands of standard (60° F. and 14.7 psi abs.) cubic feet per day.
In cases where the overhead is taken as vapor, a partial condenser is indicated by the symbol (ρ).
In general, the feed plate location was unknown, as several feed nozzles existed on each tower and data failed to record which valve was open.
Reflux drum pressures approximately (± 3) 10 psi less than tower pressures.

DATA—SECTION I *(Continued)*

TOWER	Virgin Gas Oil Stripper
Number of Plates	6
Tray Spacing	30″
Tower Diameter	5′–0″
Tower Pressure	44.5 psi gage
Tower Top Temperature	496 °F.
Tower Bottom Temperature	488 °F.
Charge Rate	828 BPD
Overhead Product Rate	125 BPD
Bottom Product Rate	703 BPD
Steam Rate	152 lb/hr.
Charge Temperature	543 °F.

COMPOSITION	Charge‡	Overhead‡	Bottoms‡
C_7	1.0	7.0	....
C_8	1.0	6.5	....
C_9	1.5	5.5	....
C_{10}	2.5	6.5	....
C_{11}	2.0	8.5	3.0
C_{12}	4.0	9.0	4.0
C_{13}	8.0	14.0	7.0
C_{14}	28.0	20.0	28.0
C_{15}	18.0	15.0	18.0
C_{16}	12.0	6.0	14.0
C_{17}	13.0	2.0	15.0
C_{18}	9.0	....	11.0

TOWER	Gas Oil Stripper
Number of Plates	6
Tray Spacing	30″
Tower Diameter	5′–0″
Tower Pressure	43.3 psi gage
Tower Top Temperature	502 °F.
Tower Bottom Temperature	461 °F.
Charge Rate	945.8 BPD
Overhead Product Rate	268.8 BPD
Bottom Product Rate	677 BPD
Steam Rate	423 lb/hr.
Charge Temperature	543 °F.

COMPOSITION	Charge‡	Overhead‡	Bottoms‡
C_7	1.5	4.5	....
C_8	1.5	4.5	....
C_9	1.5	4.5	....
C_{10}	1.5	6.5	....
C_{11}	2.5	6.5	1.5
C_{12}	4.0	8.5	1.5
C_{13}	12.5	15.0	13.5
C_{14}	21.5	25.5	20.0
C_{15}	19.5	9.0	23.5
C_{16}	14.0	6.0	18.0
C_{17}	10.5	5.0	13.0
C_{18}	9.5	4.5	9.0

TOWER	Absorber
Number of Plates	24
Plate Spacing	18″
Tower Diameter	4′–0″
Tower Pressure	238 psi gage
Lean Oil Temperature	98 °F.
Rich Oil Temperature	139 °F.
Rich Gas Temperature	136 °F.
Lean Gas Temperature	126 °F.
Lean Oil Rate	245 Mol./hr.
Rich Oil Rate	372.2 Mol./hr.
Rich Gas Rate	960.7 Mol./hr.
Lean Gas Rate	833.5 Mol./hr.
Lean Oil Molecular Weight	135
Lean Oil Gravity	46.7 °API

COMPOSITION	Rich Gas*	Lean Gas*	Rich Oil*	Lean Oil*
C_1	55.10	61.90	3.68	.....
C_2	23.00	23.74	6.15	.....
$C_3=$	6.13	5.25	4.08	.....
C_3	8.52	6.64	6.88	.....
$C_4=$	2.82	.94	5.16	.....
C_4	4.07	1.13	7.95	.....
C_5	.36	.40	1.35	2.0
L.O.	.....	.....	64.75	98.0

TOWER	Absorber
Number of Plates	24
Plate Spacing	18″
Tower Diameter	4′–0″
Tower Pressure	246 psi gage
Lean Oil Temperature	90 °F.
Rich Oil Temperature	120 °F.
Rich Gas Temperature	116 °F.
Lean Gas Temperature	120 °F.
Lean Oil Rate	1,940 BPD
Rich Oil Rate	2,490 BPD
Rich Gas Rate	13,450 MCF/Day
Lean Gas Rate	12,680 MCF/Day
Lean Oil Molecular Weight	201
Lean Oil Gravity	31.0 °API

COMPOSITION	Rich Gas*	Lean Gas*	Rich Oil*	Lean Oil*
C_1	50.2	53.0	2.4	....
$C_2=$	6.1	6.5	14.9	....
C_2	23.9	23.1		....
$C_3=$	2.7	2.4	3.1	....
C_3	12.2	12.7	1.5	....
$C_4=$	0.5	0.5	0.2	....
C_4	2.7	1.5	9.2	....
$C_5=$	0.4	0.05	2.6	....
C_5	0.1	0.25	6.1	....
C_6+	0.2	....	60.0	100.0

TOWER	Deisopentanizer
Number of Plates	30
Plate Spacing	24″
Tower Diameter	4′–0″
Tower Pressure	101 psi gage
Tower Top Temperature	175 °F.
Tower Bottom Temperature	345 °F.
Feed Temperature	290 °F.
Feed Rate	12,360 BPD
Overhead Product Rate	2,260 BPD
Bottoms Product Rate	10,100 BPD
Pumpback Reflux Rate	2,400 BPD
C_6+ Molecular Weight	110
C_6+ Gravity	48.0 °API

COMPOSITION	Feed†	Overhead‡	Bottoms†
C_3	1.6	11.7	....
C_4	15.6	64.0	5.2
$C_5=$	3.7	8.2	4.1
iC_5	3.7	8.4	2.1
nC_5	5.5	7.7	3.0
C_6+	69.9	....	85.6

NOTE: Volatility of Butane cut equivalent to Butene —1.

TOWER	Deisopentanizer
Number of Plates	30
Plate Spacing	24″
Tower Diameter	4′–0″
Tower Pressure	102 psi gage
Tower Top Temperature	170 °F.
Tower Bottom Temperature	345 °F.
Feed Temperature	293 °F.
Feed Rate	12,710 BPD
Overhead Product Rate	1,780 BPD
Bottoms Product Rate	10,930 BPD
Pumpback Reflux Rate	3,720 BPD
C_6+ Molecular Weight	116
C_6+ Gravity	49.4 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_3	1.0	5.9	....
C_4	10.5	74.9	3.4
$C_5=$	5.5	8.3	5.7
iC_5	3.0	7.6	2.1
nC_5	4.4	3.3	4.2
C_6+	75.6	....	84.6

NOTE: Volatility of Butane cut equivalent to Butene —1.

*Mol Percent.
†Liquid Volume Percent.
‡Mol percent from breakup of true-boiling-point curves.
All liquid quantities are in standard barrels (42 U. S. gallons) per day.
All vapor quantities are in thousands of standard (60° F. and 14.7 psi abs.) cubic feet per day.
In cases where the overhead is taken as vapor, a partial condenser is indicated by the symbol (*p*).
In general, the feed plate location was unknown, as several feed nozzles existed on each tower and data failed to record which valve was open.
Reflux drum pressures approximately (±3) 10 psi less than tower pressures.

DATA—SECTION I (*Continued*)

TOWER	Gas Oil Stripper
Number of Plates	6
Tray Spacing	30"
Tower Diameter	5'-0"
Tower Pressure	44.5 psi gage
Tower Top Temperature	513 °F.
Tower Bottom Temperature	501 °F.
Charge Rate	890 BPD
Overhead Product Rate	126 BPD
Bottom Product Rate	764 BPD
Steam Rate	114 lb/hr.
Charge Temperature	551 °F.

COMPOSITION	Charge‡	Overhead‡	Bottoms‡
C_7	1.5	8.5	....
C_8	1.5	8.5	....
C_9	2.0	7.0	....
C_{10}	1.5	7.0	1.5
C_{11}	2.5	7.5	2.5
C_{12}	4.0	8.0	3.5
C_{13}	17.0	11.0	17.0
C_{14}	23.0	17.0	24.0
C_{15}	17.0	15.5	16.5
C_{16}	12.0	7.0	14.5
C_{17}	10.5	3.0	11.5
C_{18}	7.5	0.0	8.5

TOWER	Absorber
Number of Plates	16
Plate Spacing	30"
Tower Diameter	5'-0"
Tower Pressure	252 psi gage
Lean Oil Temperature	132 °F.
Rich Oil Temperature	140 °F.
Rich Gas Temperature	91 °F.
Lean Gas Temperature	136 °F.
Lean Oil Rate	372.2 Mol./hr.
Rich Oil Rate	624.4 Mol./hr.
Rich Gas Rate	1,211.3 Mol./hr.
Lean Gas Rate	960.7 Mol./hr.
Molecular Weight of C_7+ Fraction in Lean Oil	135
Gravity of C_7+ Fraction in Lean Oil	46.7 °API

COMPOSITION	Rich Gas*	Lean Gas*	Rich Oil*	Lean Oil*
C_1	45.19	55.10	4.94	3.68
C_2	20.02	23.00	7.20	6.15
C_3=	5.71	6.13	4.28	4.08
C_3	9.41	8.52	8.60	6.88
C_4=	5.61	2.82	10.11	5.16
C_4	7.54	4.07	13.60	7.95
C_5	4.14	.36	8.30	1.35
C_6	2.38	.....	4.61	.....
C_7+	.....	.....	38.36	64.75

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24"
Plate Spacing (Plates 9-16)	30"
Tower Diameter	6'-0"
Tower Pressure	353 psi gage
Tower Top Temperature	181 °F.
Tower Bottom Temperature	436 °F.
Feed Temperature	235 °F.
Feed Rate	14,050 BPD
Overhead Product Rate	6,070 MCF/Day (*p*)
Bottoms Product Rate	11,810 BPD
Pumpback Reflux Rate	14,800 BPD
C_6+ Molecular Weight	112
Feed Gravity	79.1 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	1.7	22.8	....
C_2	5.0	19.4	....
C_3	6.5	38.9	0.2
C_4	6.4	16.8	10.0
C_5	6.8	2.1	14.1
C_6+	73.6	....	75.7

NOTE: Plates are numbered from top of tower.

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24"
Plate Spacing (Plates 9-16)	30"
Tower Diameter	6'-0"
Tower Pressure	335 psi gage
Tower Top Temperature	179 °F.
Tower Bottom Temperature	448 °F.
Feed Temperature	281 °F.
Feed Rate	16,050 BPD
Overhead Product Rate	6,010 MCF/Day (*p*)
Bottoms Product Rate	12,900 BPD
Pumpback Reflux Rate	15,200 BPD
C_6+ Molecular Weight	113
Feed Gravity	76.6 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	1.7	11.9	....
C_2	4.2	21.9	....
C_3	9.9	45.5	0.1
C_4	12.9	20.7	7.4
C_5	10.9	....	13.5
C_6+	60.4	....	79.0

NOTE: Plates are numbered from top of tower.

TOWER	Depropanizer
Number of Plates	26
Plate Spacing	20"
Tower Diameter	4'-6"
Tower Pressure	220 psi gage
Tower Top Temperature	121 °F.
Tower Bottom Temperature	202 °F.
Feed Temperature	120 °F.
Feed Rate	4,426 BPD
Overhead Product Rate	1,204 MCF/Day (*p*)
Bottoms Product Rate	3,640 BPD
Pumpback Reflux Rate	3,280 BPD

COMPOSITION	Feed*	Overhead*	Bottoms*
C_3=	3.4	12.6	1.1
C_3	22.3	86.3	6.6
C_4=	11.2	0.2	13.9
C_4	62.4	0.8	77.5
C_5=	0.3	0.1	0.4
C_5	0.4	....	0.5

TOWER	Depropanizer
Number of Plates	26
Plate Spacing	20"
Tower Diameter	4'-6"
Tower Pressure	220 psi gage
Tower Top Temperature	120 °F.
Tower Bottom Temperature	207 °F.
Feed Temperature	113 °F.
Feed Rate	4,610 BPD
Overhead Product Rate	4,885 MCF/Day (*p*)
Bottoms Product Rate	4,277 BPD
Pumpback Reflux Rate	3,600 BPD

COMPOSITION	Feed*	Overhead*	Bottoms*
C_3=	2.3	17.5	1.0
C_3	12.0	82.8	5.3
C_4=	28.9	0.6	31.2
C_4	53.1	1.0	57.4
C_5=	1.5	0.1	1.7
C_5	2.1	....	2.3
C_6+	0.1		0.1

*Mol Percent.
†Liquid Volume Percent.
‡Mol percent from breakup of true-boiling-point curves.
All liquid quantities are in standard barrels (42 U. S. gallons) per day.
All vapor quantities are in thousands of standard (60° F. and 14.7 psi abs.) cubic feet per day.
In cases where the overhead is taken as vapor, a partial condenser is indicated by the symbol (*p*).
In general, the feed plate location was unknown, as several feed nozzles existed on each tower and data failed to record which valve was open.
Reflux drum pressures approximately (±3) 10 psi less than tower pressures.

DATA—SECTION I (*Continued*)

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24″
Plate Spacing (Plates 9-16)	30″
Tower Diameter	6′–0″
Tower Pressure	342 psi gage
Tower Top Temperature	179 °F.
Tower Bottom Temperature	444 °F.
Feed Temperature	277 °F.
Feed Rate	17,100 BPD
Overhead Product Rate	6,410 MCF/Day (*p*)
Bottoms Product Rate	12,720 BPD
Pumpback Reflux Rate	17,000 BPD
C_6+ Molecular Weight	112
Feed Gravity	79.0 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	3.4	24.4	....
C_2	3.8	17.5	0.2
C_3	9.1	38.1	8.8
C_4	14.1	25.0	13.7
C_5	10.9	2.2	77.3
C_6+	58.7	....	....

NOTE: Plates are numbered from top of tower.

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24″
Plate Spacing (Plates 9-16)	30″
Tower Diameter	6′–0″
Tower Pressure	351 psi gage
Tower Top Temperature	180 °F.
Tower Bottom Temperature	446 °F.
Feed Temperature	334 °F.
Feed Rate	16,820 BPD
Overhead Product Rate	5,720 MCF/Day (*p*)
Bottoms Product Rate	13,100 BPD
Pumpback Reflux Rate	11,600 BPD
C_6+ Molecular Weight	114
Feed Gravity	77.5 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	2.5	18.8	....
C_2	5.2	26.3	....
C_3	9.5	43.1	0.1
C_4	8.3	11.8	6.8
C_5	10.0	....	12.6
C_6+	64.3	....	80.5

NOTE: Plates are numbered from top of tower.

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24″
Plate Spacing (Plates 9-16)	30″
Tower Diameter	6′–0″
Tower Pressure	348 psi gage
Tower Top Temperature	185 °F.
Tower Bottom Temperature	453 °F.
Feed Temperature	324 °F.
Feed Rate	17,420 BPD
Overhead Product Rate	5,640 MCF/Day (*p*)
Bottoms Product Rate	13,420 BPD
Pumpback Reflux Rate	13,820 BPD
C_6+ Molecular Weight	113
Feed Gravity	77.3 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	1.3	10.0	....
C_2	4.5	28.6	....
C_3	10.5	46.1	0.2
C_4	13.4	15.3	10.1
C_5	10.6	....	13.9
C_6+	59.7	....	75.8

NOTE: Plates are numbered from top of tower.

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24″
Plate Spacing (Plates 9-16)	30″
Tower Diameter	6′–0″
Tower Pressure	335 psi gage
Tower Top Temperature	179 °F.
Tower Bottom Temperature	448 °F.
Feed Temperature	281 °F.
Feed Rate	16,050 BPD
Overhead Product Rate	6,010 MCF/Day (*p*)
Bottoms Product Rate	12,900 BPD
Pumpback Reflux Rate	15,200 BPD
C_6+ Molecular Weight	113
Feed Gravity	76.6 API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	1.7	11.9	....
C_2	4.2	21.9	....
C_3	9.9	45.5	0.1
C_4	12.9	20.7	7.4
C_5	10.9	....	13.5
C_6+	60.4	....	79.0

NOTE: Plates are numbered from top of tower.

TOWER	Debutanizer
Number of Plates	24
Plate Spacing	30″
Tower Diameter	6′–0″
Tower Pressure	132 psi gage
Tower Top Temperature	156 °F.
Tower Bottom Temperature	392 °F.
Feed Temperature	267 °F.
Feed Rate	11,916 BPD
Overhead Product Rate	4,426 BPD
Bottoms Product Rate	7,490 BPD
Pumpback Reflux Rate	11,180 BPD
C_6+ Molecular Weight	164
C_6+ Gravity	41.7 °API

COMPOSITION	Feed*	Overhead*	Bottoms*
C_3=	1.7	3.4	....
C_3	11.4	22.3	....
C_4=	6.2	11.2	1.0
C_4	33.8	62.4	3.5
C_5=	1.1	0.3	2.0
C_5	6.3	0.4	12.6
C_6+	39.5	....	80.9

TOWER	Debutanizer
Number of Plates	24
Plate Spacing	30″
Tower Diameter	6′–0″
Tower Pressure	131 psi gage
Tower Top Temperature	156 °F.
Tower Bottom Temperature	388 °F.
Feed Temperature	346 °F.
Feed Rate	8,773 BPD
Overhead Product Rate	1,603 BPD
Bottoms Product Rate	7,170 BPD
Pumpback Reflux Rate	11,170 BPD
C_6+ Molecular Weight	157
C_6+ Gravity	43.5 °API

COMPOSITION	Feed*	Overhead*	Bottoms*
C_3=	0.7	2.2	....
C_3	5.6	20.4	....
C_4=	6.6	17.1	2.3
C_4	21.8	60.1	4.8
C_5=	3.9	0.1	5.4
C_5	3.4	0.1	4.8
C_6+	58.0	....	82.7

*Mol Percent.
†Liquid Volume Percent.
‡Mol percent from breakup of true-boiling-point curves.
All liquid quantities are in standard barrels (42 U. S. gallons) per day.
All vapor quantities are in thousands of standard (60° F. and 14.7 psi abs.) cubic feet per day.
In cases where the overhead is taken as vapor, a partial condenser is indicated by the symbol (*p*).
In general, the feed plate location was unknown, as several feed nozzles existed on each tower and data failed to record which valve was open.
Reflux drum pressures approximately (±3) 10 psi less than tower pressures.

DATA—SECTION I (*Continued*)

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24″
Plate Spacing (Plates 9-16)	30″
Tower Diameter	6′–0″
Tower Pressure	351 psi gage
Tower Top Temperature	180 °F.
Tower Bottom Temperature	446 °F.
Feed Temperature	334 °F.
Feed Rate	16,820 BPD
Overhead Product Rate	5,720 MCF/Day (*p*)
Bottoms Product Rate	13,100 BPD
Pumpback Reflux Rate	11,600 BPD
C_6+ Molecular Weight	114
Feed Gravity	77.5 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	2.5	18.8	....
C_2	5.2	26.3	....
C_3	9.5	43.1	0.1
C_4	8.3	11.8	6.8
C_5	10.0	....	12.6
C_6+	64.3	....	80.5

NOTE: Plates are numbered from top of tower.

TOWER	Stabilizer
Number of Plates	16
Plate Spacing (Plates 1-8)	24″
Plate Spacing (Plates 9-16)	30″
Tower Diameter	6′–0″
Tower Pressure	332 psi gage
Tower Top Temperature	181 °F.
Tower Bottom Temperature	448 °F.
Feed Temperature	277 °F.
Feed Rate	15,100 BPD
Overhead Product Rate	6,390 MCF/Day (*p*)
Bottoms Product Rate	12,180 BPD
Pumpback Reflux Rate	14,900 BPD
C_6+ Molecular Weight	112
Feed Gravity	78.0 ° API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_1	1.1	17.7	....
C_2	3.7	26.0	....
C_3	9.4	46.6	0.1
C_4	13.8	9.7	8.7
C_5	13.3	....	16.1
C_6+	58.7	....	74.1

NOTE: Plates are numbered from top of tower.

TOWER	Kerosene Stripper
Number of Plates	4
Plate Spacing	30″
Tower Diameter	5′–0″
Tower Pressure	53.2 psi gage
Tower Top Temperature	456 °F.
Tower Bottom Temperature	411 °F.
Charge Rate	6,084 BPD
Overhead Product Rate	780 BPD
Bottom Product Rate	5,304 BPD
Steam Rate	624 lb/hr.
Charge Temperature	483 °F.

COMPOSITION	Charge‡	Overhead‡	Bottoms‡
C_6	1.0	6.0	....
C_7	1.5	11.5	....
C_8	3.0	10.5	2.2
C_9	3.5	10.0	2.0
C_{10}	7.0	14.5	5.5
C_{11}	12.0	13.5	11.8
C_{12}	18.0	16.5	17.3
C_{13}	18.0	8.5	19.0
C_{14}	21.0	5.0	23.3
C_{15}	13.0	3.5	14.5
C_{16}	2.0	0.5	1.7

TOWER	Kerosene Stripper
Number of Plates	4
Plate Spacing	30″
Tower Diameter	5′–0″
Tower Pressure	54 psi gage
Tower Top Temperature	450 °F.
Tower Bottom Temperature	444 °F.
Charge Rate	6,511 BPD
Overhead Product Rate	1,319 BPD
Bottom Product Rate	5,192 BPD
Steam Rate	1,469 lb/hr
Charge Temperature	485 °F.

COMPOSITION	Charge‡	Overhead‡	Bottoms‡
C_7	2.0	12.5	....
C_8	3.0	8.0	....
C_9	3.5	8.5	2.1
C_{10}	5.5	13.0	4.5
C_{11}	10.0	14.0	9.5
C_{12}	16.0	17.0	16.5
C_{13}	22.5	12.5	25.0
C_{14}	13.5	8.0	18.5
C_{15}	16.0	5.0	18.0
C_{16}	8.0	1.0	9.0

TOWER	Deisopentanizer
Number of Plates	30
Plate Spacing	24″
Tower Diameter	4′–0″
Tower Pressure	102 psi gage
Tower Top Temperature	165 °F.
Tower Bottom Temperature	345 °F.
Feed Temperature	288 °F.
Feed Rate	12,490 BPD
Overhead Product Rate	1,682 BPD
Bottoms Product Rate	10,808 BPD
Pumpback Reflux Rate	2,880 BPD
C_6+ Molecular Weight	112
C_6+ Gravity	49.4 °API

COMPOSITION	Feed*	Overhead*	Bottoms†
C_3	1.0	10.5	....
C_4	10.4	70.6	5.9
C_5=	5.9	6.5	5.9
iC_5	3.5	8.8	2.3
nC_5	4.0	3.6	4.0
C_6+	75.2	....	81.9

NOTE: Volatility of Butane cut equivalent to Butene —1.

TOWER	Debutanizer
Number of Plates	27
Plate Spacing	24″
Tower Diameter	6′–0″
Tower Pressure	101 psi gage
Tower Top Temperature	170 °F.
Tower Bottom Temperature	380 °F.
Feed Temperature	300 °F.
Feed Rate	12,850 BPD
Overhead Product Rate	3,660 BPD
Bottoms Product Rate	9,190 BPD
Pumpback Reflux Rate	9,730 BPD
C_6 Molecular Weight	120
C_6+—120 Molecular Weight—Gravity	50 °API

COMPOSITION	Feed†	Overhead*	Bottoms†
C_3	1.3	9.9	....
C_4	15.8	61.2	0.1
C_5=	3.3	10.5	4.0
iC_5	5.9	8.2	1.4
nC_5	6.1	10.2	2.3
C_6+	67.6	....	92.1

NOTE: Bottom 11 plates of tower perforated. Volatility of Butane cut equivalent to Butene —1.

*Mol Percent.
†Liquid Volume Percent.
‡Mol percent from breakup of true-boiling-point curves.
All liquid quantities are in standard barrels (42 U. S. gallons) per day.
All vapor quantities are in thousands of standard (60° F. and 14.7 psi abs.) cubic feet per day.
In cases where the overhead is taken as vapor, a partial condenser is indicated by the symbol (*p*).
In general, the feed plate location was unknown, as several feed nozzles existed on each tower and data failed to record which valve was open.
Reflux drum pressures approximately (±3) 10 psi less than tower pressures.

DATA—SECTION II

The Results of Calculations on the Data in this Section are not plotted in Figure 1A, but are presented in Table 4

COLUMN I—
Key Components
Isobutane and Normal Butane

Number of Plates	16
Plate Spacing 1-8 (from top)	24″
9-16	30″
Tower Diameter	6′–0″

Column I has a partial condenser

C_6+ Cut

Molecular Weight	110
Gravity	52 °API
Equilibrium Constant	.8 × *K* for Heptane

Viscosity of C_6+ Cut

	Saybolt Thermo	Centipoises
60°	14.2	.67
120°	10.1	.44

Use viscosity half way between C_8 and C_9.
The high viscosity is due to presence of a large amount of naphthenes.

Test I

COLUMN I—	
Tower Top Temperature	183 °F.
Tower Bottom Temperature	432 °F.
Tower Pressure	355 psig
Reflux Drum Pressure	340 psig
Feed Temperature	322 °F.
Feed Rate	1,801.3
Overhead Product Rate	512.4
Bottoms Product Rate	1,288.9
Pumpback Reflux Rate	2,075

COMPOSITION	Feed	Overhead	Bottoms
C_1	94.5	94.5	....
$C_2=$	22.6	22.6	....
C_2	146.8	146.8	....
$C_3=$	63.6	63.6	....
C_3	147.9	145.9	2.0
iC_4	101.4	19.0	82.4
$C_4=$	36.1	9.7	26.4
nC_4	97.3	10.3	87.0
iC_5	123.6	....	123.6
C_5	42.5	....	42.5
nC_5	80.0	....	80.0
C_6+	845.0	....	845.0

All quantities in Mols per hour

Test II

COLUMN I—	
Tower Top Temperature	173 °F.
Tower Bottom Temperature	434 °F.
Tower Pressure	355 psig
Reflux Drum Pressure	340 psig
Feed Temperature	318 °F.
Feed Rate	1,887.5
Overhead Product Rate	520.5
Bottoms Product Rate	1,367.0
Pumpback Reflux Rate	2,160.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	115.1	115.1	.....
$C_2=$	25.1	25.1	.....
C_2	157.5	157.5	.....
$C_3=$	66.5	66.5	.....
C_3	136.4	132.2	4.2
iC_4	29.1	9.4	19.7
$C_4=$	122.4	8.4	114.0
nC_4	123.9	6.3	117.6
iC_5	41.0	.....	41.0
$C_5=$	105.0	.....	105.0
nC_5	76.5	.....	76.5
C_6+	889.0	.....	889.0

All quantities in Mols per hour

Test III

COLUMN I—	
Tower Top Temperature	167 °F.
Tower Bottom Temperature	437 °F.
Tower Pressure	355 psig
Reflux Drum Pressure	340 psig
Feed Temperature	319 °F.
Feed Rate	1,819.2
Overhead Product Rate	453.2
Bottoms Product Rate	1,366.0
Pumpback Reflux Rate	2,180.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	62.6	62.6	.....
$C_2=$	16.8	16.8	.....
C_2	125.1	125.1	.....
$C_3=$	65.4	65.4	.....
C_3	143.1	143.1	.....
iC_4	102.5	79.9	22.6
$C_4=$	106.9	10.4	96.5
nC_4	116.5	8.9	107.6
iC_5	50.5	1.2	49.3
$C_5=$	81.3	.....	81.3
nC_5	110.7	.....	110.7
C_6+	898.0	.....	898.0

All quantities in Mols per hour

Test IV

COLUMN I—	
Tower Top Temperature	172 °F.
Tower Bottom Temperature	436 °F.
Tower Pressure	351 psig
Reflux Drum Pressure	334 psig
Feed Temperature	321 °F.
Feed Rate	1,971.1
Overhead Product Rate	499.8
Bottoms Product Rate	1,471.3
Pumpback Reflux Rate	2,310.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	85.3	85.3	.....
$C_2=$	19.1	19.1	.....
C_2	145.0	145.0	.....
$C_3=$	72.2	72.2	.....
C_3	147.5	143.2	4.3
iC_4	38.9	13.5	25.4
C_4	114.7	15.0	99.7
nC_4	128.3	6.5	121.8
iC_5	30.8	.....	30.8
$C_5=$	131.8	.....	131.8
nC_5	94.5	.....	94.5
C_6+	963.0	.....	963.0

All quantities in Mols per hour

Test V

COLUMN I—	
Tower Top Temperature	176 °F.
Tower Bottom Temperature	433 °F.
Tower Pressure	349 psig
Reflux Drum Pressure	336 psig
Feed Temperature	321 °F.
Feed Rate	1,838.7
Overhead Product Rate	457.2
Bottoms Product Rate	1,381.5
Pumpback Reflux Rate	2,130.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	78.2	78.2	.....
$C_2=$	17.5	17.5	.....
C_2	125.5	125.5	.....
$C_3=$	73.5	73.5	.....
C_3	128.2	126.2	2.0
iC_4	28.5	11.8	16.7
$C_4=$	112.0	17.0	95.0
nC_4	122.6	7.5	115.1
iC_5	46.8	.....	46.8
C_5	120.1	.....	120.1
nC_5	82.8	.....	82.8
C_6+	903.0	.....	903.0

All quantities in Mols per hour

Test VI

COLUMN I—	
Tower Top Temperature	180 °F.
Tower Bottom Temperature	429 °F.
Tower Pressure	352 psig
Reflux Drum Pressure	336 psig
Feed Temperature	316 °F.
Feed Rate	1,810.7
Overhead Product Rate	546.2
Bottoms Product Rate	1,264.5
Pumpback Reflux Rate	2,040.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	110.0	110.0	.....
$C_2=$	32.1	32.1	.....
C_2	148.8	148.8	.....
$C_3=$	77.4	77.4	.....
C_3	139.6	133.9	5.7
iC_4	28.5	12.2	16.3
$C_4=$	104.3	23.3	81.0
nC_4	105.9	8.5	97.4
iC_5	49.4	.....	49.4
$C_5=$	120.0	.....	120.2
nC_5	78.5	.....	78.5
C_6+	816.0	.....	816.0

All quantities in Mols per hour

DATA—SECTION II *(Continued)*

Test VII

COLUMN I—	
Tower Top Temperature	167 °F.
Tower Bottom Temperature	437 °F.
Tower Pressure	356 psig
Reflux Drum Pressure	340 psig
Feed Temperature	319 °F.
Feed Rate	2,055.8
Overhead Product Rate	504.1
Bottoms Product Rate	1,551.7
Pumpback Reflux Rate	2,445.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	89.5	89.5	.....
$C_2=$	23.9	23.9	.....
C_2	138.2	138.2	.....
$C_3=$	75.2	75.2	.....
C_3	144.6	135.1	9.5
iC_4	34.4	17.8	16.6
$C_4=$	112.5	14.0	98.5
nC_4	110.4	10.8	100.0
iC_5	54.3	.....	54.3
$C_5=$	138.4	.....	138.4
nC_5	86.4	.....	86.4
C_6+	1048.0	.....	1048.0

All quantities in Mols per hour

Test VIII

COLUMN I—	
Tower Top Temperature	175 °F.
Tower Bottom Temperature	435 °F.
Tower Pressure	348 psig
Reflux Drum Pressure	334 psig
Feed Temperature	316 °F.
Feed Rate	1,718.2
Overhead Product Rate	443.8
Bottoms Product Rate	1,274.4
Pumpback Reflux Rate	2,005.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	81.5	81.5	.....
$C_2=$	26.3	26.3	.....
C_2	108.9	108.9	.....
$C_3=$	105.1	105.1	.....
C_3	97.0	86.1	10.9
iC_4	20.6	9.4	11.2
$C_4=$	98.7	18.3	80.4
nC_4	106.0	8.2	97.8
iC_5	31.3	.....	31.3
$C_5=$	82.0	.....	82.0
nC_5	70.8	.....	70.8
C_6+	890.0	.....	890.0

All quantities in Mols per hour

Test IX

COLUMN I—	
Tower Top Temperature	167 °F.
Tower Bottom Temperature	436 °F.
Tower Pressure	350 psig
Reflux Drum Pressure	335 psig
Feed Temperature	322 °F.
Feed Rate	1,684.3
Overhead Product Rate	425.7
Bottoms Product Rate	1,258.6
Pumpback Reflux Rate	1,980.0

COMPOSITION	Feed	Overhead	Bottoms
C_1	81.0	81.0	.....
$C_2=$	29.7	29.7	.....
C_2	125.8	125.8	.....
$C_3=$	54.8	54.8	.....
C_3	87.9	87.9	.....
iC_4	34.1	15.3	18.8
$C_4=$	103.3	22.9	80.4
nC_4	105.8	8.2	97.5
iC_5	43.2	.....	43.2
$C_5=$	125.1	.....	125.1
nC_5	53.6	.....	53.6
C_6+	840.0	.....	840.0

All quantities in Mols per hour

Test X

COLUMN I—	
Tower Top Temperature	172 °F.
Tower Bottom Temperature	435 °F.
Tower Pressure	348 psig
Reflux Drum Pressure	334 psig
Feed Temperature	320 °F.
Feed Rate	1,734.3
Overhead Product Rate	433.5
Bottoms Product Rate	1,300.8
Pumpback Reflux Rate	2,055.0

COMPOSITION	Feed,	Overhead	Bottoms
C_1	77.5	77.5	.....
$C_2=$	23.8	23.8	.....
C_2	116.0	116.0	.....
$C_3=$	77.5	77.5	.....
C_3	105.9	100.9	5.0
iC_4	19.7	9.3	10.4
$C_4=$	106.1	19.1	87.0
nC_4	112.7	9.4	103.3
iC_5	43.6	.....	43.6
$C_5=$	127.0	.....	127.0
nC_5	51.5	.....	51.5
C_6+	873.0	.....	873.0

All quantities in Mols per hour

COLUMN II—
Key Components
Isopentane and Normal Pentane

Number of Plates	27
Plate Spacing	24″
Tower Diameter	6′–0″

Column II has a total condenser
The lower 11 plates are perforated

C_6+ Cut

Molecular Weight	110
Gravity	52 °API
Equilibrium Constant	.8 × K for Heptane

Viscosity of C_6+ Cut

	Saybolt Thermo	Centipoises
60°	14.2	.67
120°	10.1	.44

Use viscosity halfway between C_8 and C_9.
The high viscosity is due to presence of a large amount of naphthenes.

Test I

COLUMN II—	
Tower Top Temperature	153 °F.
Tower Bottom Temperature	335 °F.
Tower Pressure	84 psig
Reflux Drum Pressure	72 psig
Feed Temperature	300 °F. (at 355 psig)
Feed Rate	1,288.9
Overhead Product Rate	221.3
Bottoms Product Rate	1,067.6
Pumpback Reflux Rate	1,091.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	2.0	2.0	.....
iC_4	82.4	82.4	.....
$C_4=$	26.4	26.4	.....
nC_4	87.0	85.6	1.4
iC_5	123.6	11.0	112.6
$C_5=$	42.5	9.7	32.8
nC_5	80.0	4.2	75.8
C_6+	845.0	.....	845.0

All quantities in Mols per hour

Test II

COLUMN II—	
Tower Top Temperature	159 °F.
Tower Bottom Temperature	343 °F.
Tower Pressure	82 psig
Reflux Drum Pressure	60 psig
Feed Temperature	300 °F. (at 355 psig)
Feed Rate	1,367.0
Bottoms Product Rate	1,094.7
Overhead Product Rate	272.3
Pumpback Reflux Rate	1,161.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	4.2	4.2	.....
iC_4	19.7	19.7	.....
$C_4=$	114.0	114.0	.....
nC_4	117.6	108.7	8.9
iC_5	41.0	9.5	31.5
$C_5=$	105.0	12.8	92.2
nC_5	76.5	3.4	73.1
C_6+	889.0	.....	889.0

All quantities in Mols per hour

DATA—SECTION II (*Continued*)

Test III

COLUMN II—	
Tower Top Temperature	160 °F.
Tower Bottom Temperature	347 °F.
Tower Pressure	80 psig
Reflux Drum Pressure	65 psig
Feed Temperature	300 °F. (at 350 psig)
Feed Rate	1,366.0
Overhead Product Rate	252.9
Bottoms Product Rate	1,113.1
Pumpback Reflux Rate	1,110.0

COMPOSITION	Feed	Overhead	Bottoms
iC_4	22.6	20.7	1.9
$C_4=$	96.5	91.9	4.6
nC_4	107.6	103.0	4.6
iC_5	49.3	10.9	38.4
$C_5=$	81.3	20.8	60.5
nC_5	110.7	5.6	105.1
C_6+	898.0	.....	898.0

All quantities in Mols per hour

Test IV

COLUMN II—	
Tower Top Temperature	162 °F.
Tower Bottom Temperature	344 °F.
Tower Pressure	84 psig
Reflux Drum Pressure	70 psig
Feed Temperature	300 °F. (at 351 psig)
Feed Rate	1,471.3
Overhead Product Rate	268.4
Bottoms Product Rate	1,202.9
Pumpback Reflux Rate	1,119.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	4.3	4.3	.....
iC_4	25.4	25.4	.....
$C_4=$	99.7	91.0	8.7
nC_4	121.8	108.5	13.3
iC_5	30.8	10.0	20.8
$C_5=$	131.8	22.2	109.6
nC_5	94.5	7.0	87.5
C_6+	963.0	.....	963.0

All quantities in Mols per hour

Test V

COLUMN II—	
Tower Top Temperature	164 °F.
Tower Bottom Temperature	141 °F.
Tower Pressure	77 psig
Reflux Drum Pressure	58 psig
Feed Temperature	300 °F. (at 349 psig)
Feed Rate	1,381.5
Overhead Product Rate	248.1
Bottoms Product Rate	1,133.5
Pumpback Reflux Rate	1,090.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	2.0	2.0	.....
iC_4	16.7	16.7	.....
$C_4=$	95.0	95.0	.....
nC_4	115.1	100.0	15.1
iC_5	46.8	13.1	33.7
$C_5=$	120.1	16.2	103.9
nC_5	82.8	5.0	77.8
C_6+	903.0	.....	903.0

All quantities in Mols per hour

Test VI

COLUMN II—	
Tower Top Temperature	161 °F.
Tower Bottom Temperature	347 °F.
Tower Pressure	86 psig
Reflux Drum Pressure	68 psig
Feed Temperature	300 °F. (at 352 psig)
Feed Rate	1,264.5
Overhead Product Rate	236.5
Bottoms Product Rate	1,028.0
Pumpback Reflux Rate	1,065.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	5.7	5.7	.....
iC_4	16.3	16.3	.....
$C_4=$	81.0	81.0	.....
nC_4	97.4	91.4	6.0
iC_5	49.4	17.0	32.3
$C_5=$	120.2	19.0	101.2
nC_5	78.5	6.0	72.5
C_6+	816.0	.....	816.0

All quantities in Mols per hour

Test VII

COLUMN II—	
Tower Top Temperature	163 °F.
Tower Bottom Temperature	345 °F.
Tower Pressure	86 psig
Reflux Drum Pressure	73 psig
Feed Temperature	300 °F. (at 356 psig)
Feed Rate	1,551.7
Overhead Product Rate	275.3
Bottoms Product Rate	1,276.4
Pumpback Reflux Rate	1,071.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	9.5	9.5	.....
iC_4	16.6	13.2	3.4
$C_4=$	98.5	81.2	17.3
nC_4	100.0	87.0	12.3
iC_5	54.3	28.9	25.4
$C_5=$	138.4	41.6	96.8
nC_5	86.4	13.2	73.2
C_6+	1048.0	.....	1048.0

All quantities in Mols per hour

Test VIII

COLUMN II—	
Tower Top Temperature	157 °F.
Tower Bottom Temperature	352 °F.
Tower Pressure	86 psig
Reflux Drum Pressure	72 psig
Feed Temperature	300 °F. (at 348 psig)
Feed Rate	1,274.4
Overhead Product Rate	222.2
Bottoms Product Rate	1,052.2
Pumpback Reflux Rate	1,059.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	10.9	10.9	.....
iC_4	11.2	11.2	.....
$C_4=$	80.4	80.4	.....
nC_4	97.8	86.3	11.5
iC_5	31.3	10.7	20.6
$C_5=$	82.0	17.8	64.2
nC_5	70.8	4.7	66.1
C_6+	890.0	.....	890.0

All quantities in Mols per hour

Test IX

COLUMN II—	
Tower Top Temperature	160 °F.
Tower Bottom Temperature	353 °F.
Tower Pressure	91 psig
Reflux Drum Pressure	78 psig
Feed Temperature	300 °F. (at 350 psig)
Feed Rate	1,258.6
Overhead Product Rate	238.3
Bottoms Product Rate	1,020.3
Pumpback Reflux Rate	1,162.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	.....	.....	.....
iC_4	18.8	18.8	.....
$C_4=$	80.4	80.4	.....
nC_4	97.5	90.5	7.0
iC_5	43.2	14.1	29.7
$C_5=$	125.1	30.5	94.6
nC_5	53.6	4.0	49.6
C_6+	840.0	.....	840.0

All quantities in Mols per hour

Test X

COLUMN II—	
Tower Top Temperature	161 °F.
Tower Bottom Temperature	347 °F.
Tower Pressure	78 psig
Reflux Drum Pressure	62 psig
Feed Temperature	300 °F. (at 348 psig)
Feed Rate	1,300.0
Overhead Product Rate	268.6
Bottoms Product Rate	1,032.2
Pumpback Reflux Rate	1,031.0

COMPOSITION	Feed	Overhead	Bottoms
C_3	5.0	5.0	.....
iC_4	10.4	10.4	.....
$C_4=$	87.0	87.0	.....
nC_4	103.3	99.0	4.3
iC_5	43.6	24.2	19.4
$C_5=$	127.0	32.9	94.1
nC_5	51.5	10.1	41.4
C_6+	873.0	.....	873.0

All quantities in Mols per hour

Automatic Process Control And Cycle Timers

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CATALYTIC crackers and reformers of the fixed bed or static type used in production of high-octane gasoline, toluene, and butadiene, require re-activation of the catalyst at regular intervals. In a typical process, catalyst regeneration in a given re-action vessel (or "reactor") is required after a predetermined time on stream and includes: (1) diversion of the stock feed; (2) admission of purging steam or gas; (3) admission of air- or oxygen-containing flue gas to burn off the coke, and (4) air purge, after which, the unit is ready to go on stream once more.

This inherently batch operation is adapted for continuous production by utilizing from two to six or more reaction vessels and switching the feed from one to another as the catalyst is spent. If the on-stream period is only one third of the total time of a cycle, a minimum of three reactors are required for continuous output. This is analagous to the operation of a multi-cylinder internal combustion engine, where the power output is intermittent from each cylinder but continuous at the shaft.

These "fixed-bed" catalytic processes—and other processes having similar cycling requirements—involve the opening and closing of a large number of motor- or solenoid-operated valves and dampers at definite times and in a definitely recurring, complex sequence. To permit process changes, the schedules must be adjustable and re-arrangeable.

In most plants, the job of control of valve operation is taken over by an electrically-operated timing system, as it early became evident that, even if the required number of skilled operators were available, it would be humanly impossible for them to open and close the valves with the precise timing that the process demands for maximum output. Automatic process control reduces the required number of operators, frees operators from much routine work, and may, through increased reliability and precise control of flow "traffic," permit simplification of the piping layout and saving of materials.

The heart of the automatic process control system is the synchronous-motor-driven cycle timer, which is used in two basic types. Where only a few valves are to be controlled (approximately 8 or 10), the timer often consists of a motor-driven cam shaft with a cam for each switch and one or two cam-operated switches for each valve. Each cam may be mechanically rotated with respect to the shaft and is set to close or to open the switch and consequently the valve which the switch controls, at the desired time intervals, depending on the initial adjustment of the cam and also on the process requirements.

Where from 18 to 75, or more, valves are to be controlled, correspondingly more timer circuits are required, interlocking requirements are usually more complex, and greater speed and flexibility of adjustment are desirable. For units of this type—which this article discusses—another type of timer is used. This will be described in more detail later but basically it includes a large number of contact points or segments (10 or more per valve), which are successively energized at regular intervals (usually 5 to 10 seconds), through a synchronous motor-driven traveling arm. The valve controls are plugged into some of these points so as to open and close each valve at the desired time intervals, which may be changed by shifting the flexible plug-in connectors to other points.

While the variable-cycle timer is the heart of such a system of valve control, considerable other equipments such as valve operator reversing contactors, relays, position-indicating lights, auxiliary timers and selector switches, are involved in the complete, coordinated valve-control system, as discussed here.

What the System Does

The equipment, in general, performs the following functions:

1. Opens or closes the proper valves and dampers at the proper time;
2. Checks the position (as indicated by valve-limit switches) to make sure previous valve or valves have properly opened or closed before permitting next valve to open or close.
3. Rings an alarm bell and shuts down timer (optional) if previous valve is not in correct position;
4. Provides operator's control panel with one-line diagram (when desired) of process, with indicating

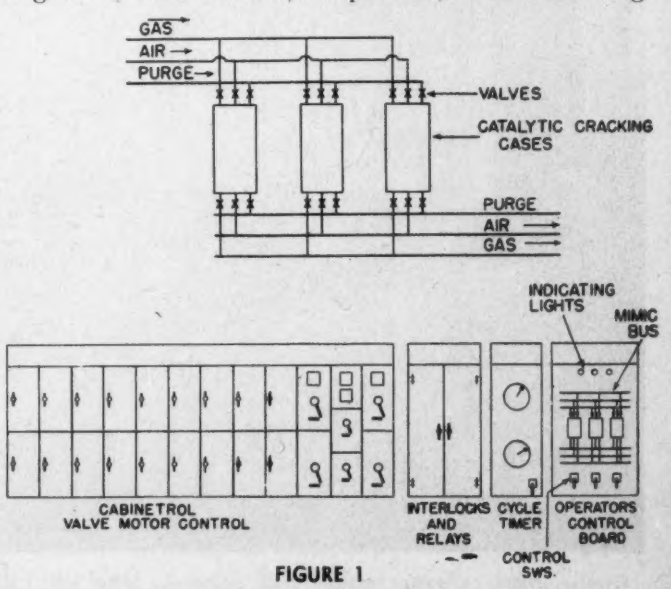


FIGURE 1
Component parts of typical cycle-timer and valve operated control.

lights showing position of valves, and with control switches for manual operation;

5. Provides means for adjusting time of process and rearranging sequence of events to suit new or unforeseen conditions, such as change in process.

Depending on process requirements, a complete cycle of operation may require from 20 minutes to 3 hours, or more. The number of valves and other devices to be controlled may be from 18 to 75, or more. The timer has from 100 to 900 points, or timing intervals, and usually is provided with several extra gears which—with the dormant timers—permit changing the total time of a cycle over a wide range.

What the System Is

The component parts of the control (see Figure 1) include:

1. Reversing contactors with fused switch or circuit breaker for each valve-operator motor control;
2. Synchronous-motor-driven cycle-timer;
3. Interlocking and alarm relays;
4. Valve-position indicating lights, with painted "dummy" flow chart when needed (see Figure 4);
5. Auxiliary timers, usually referred to as dormant timers, to shut down main timer during periods when opening and closing of the valves are not required;
6. Selector switches and push-buttons for emergency manual operation.

For each motor-operated valve, there are provided forward and reverse contactors, mechanically and electrically interlocked, and having a fused switch or air circuit breaker and a temperature overload relay. These individual control panels are assembled in a compact, metal-enclosed housing as shown in Figure 2.

In this enclosure are also mounted the control transformer, and incoming line and auxiliary circuit feeder breakers; and in addition, control units for miscellaneous other motors, when required.

Auxiliary relays, selector switches, push-buttons, valve-position-indicating lights, and dormant timers may be mounted in or on a similar enclosure. Alternatively, switches and auxiliary timers may be mounted on the refinery control board, in which case they may be explosion-proof. The refinery control board, supplied by the user, includes temperature indicators and other devices essential to control of the whole process.

Where the location is "hazardous," an area behind the refinery control board is enclosed and ventilated, or sealed and kept under slight internal air pressure. This provides a non-hazardous location for the valve-operator control and other back-of-board equipment. Therefore, this equipment does not have to be explosion-proof.

It should be understood that a 70-valve unit, for example, does not ordinarily require anywhere near 70 valve-operator control units, as perhaps one half of these valves may be solenoid-operated and controlled directly from the timer or through latched-in relays.

The Master Timer

There are cycle-timers available in a number of sizes and arrangements to meet process requirements; the number of timing points or buttons ranges from 100 to approximately 900. There is no fixed ratio between the number of valves to be controlled and the number of timer points, but a study of 6 installations, selected at random, shows from 6 to 16 points per valve, with an average of 10 or more.

The timers are arranged for mounting either back-

FIGURE 2

Dead-front Cabinetrol housing for individual control panels of the valve-operated control.

of-board or integral with the refinery control board, and are further designated as "rotary" or "vertical" type, according to the motion of the traveling arm and the arrangement of the segments. Figure 3 shows a rear view of a typical "rotary" type timer for back-of-board mounting. Figure 4 shows a typical "rotary" type of timer for integral mounting. The choice of "rotary" or "vertical" type timers depends more on such factors as customer preference, duplication of previous installations, and manufacturing expediency than on any basic functional difference.

Most cycle-timers have the following features:

1. A terminal board for connection of the valve-operator or control leads to the timer;

2. Flexible leads (2 per valve plus extras for relays, etc.) with plug-type terminals for connection to desired timer points, to open or close the valve at the desired time corresponding to that point;

3. 100 to 900 segments, arranged in vertical rows or concentric circles and connected to jacks. Each point is successively energized during a complete cycle by means of:

(a) A traveling arm, synchronous-motor-driven through gears, and

(b) A synchronized, cam-operated (quick-break) contact-making mechanism (driven by the same synchronous motor) which closes and then breaks the circuit when the arm is in the middle of each button. No circuits are made or broken at the timer button. This feature contributes greatly to long life of contacts and the elimination of "sneak" circuits;

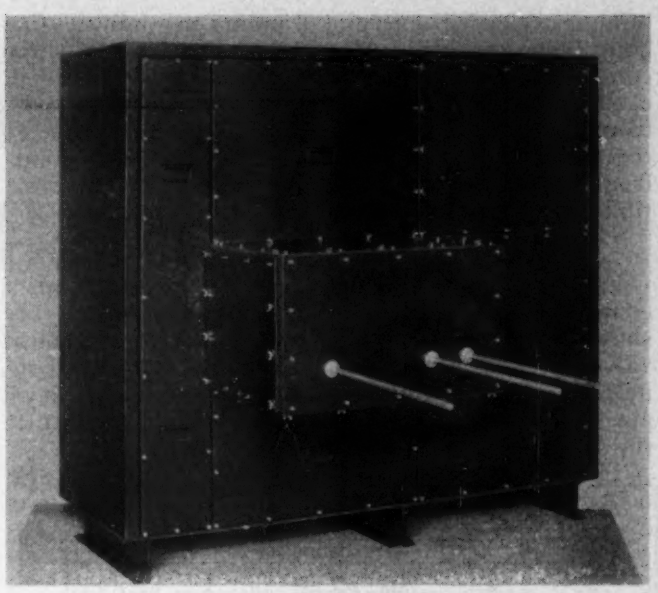


FIGURE 3

Rear view of typical "rotary" type timer for back-of-board mounting.

4. A gear train arranged to provide change in time of cycle by change in the gear ratio;

5. Provision for manual operation and for indication of timer position.

A 360-point timer, for example, geared for a 60-

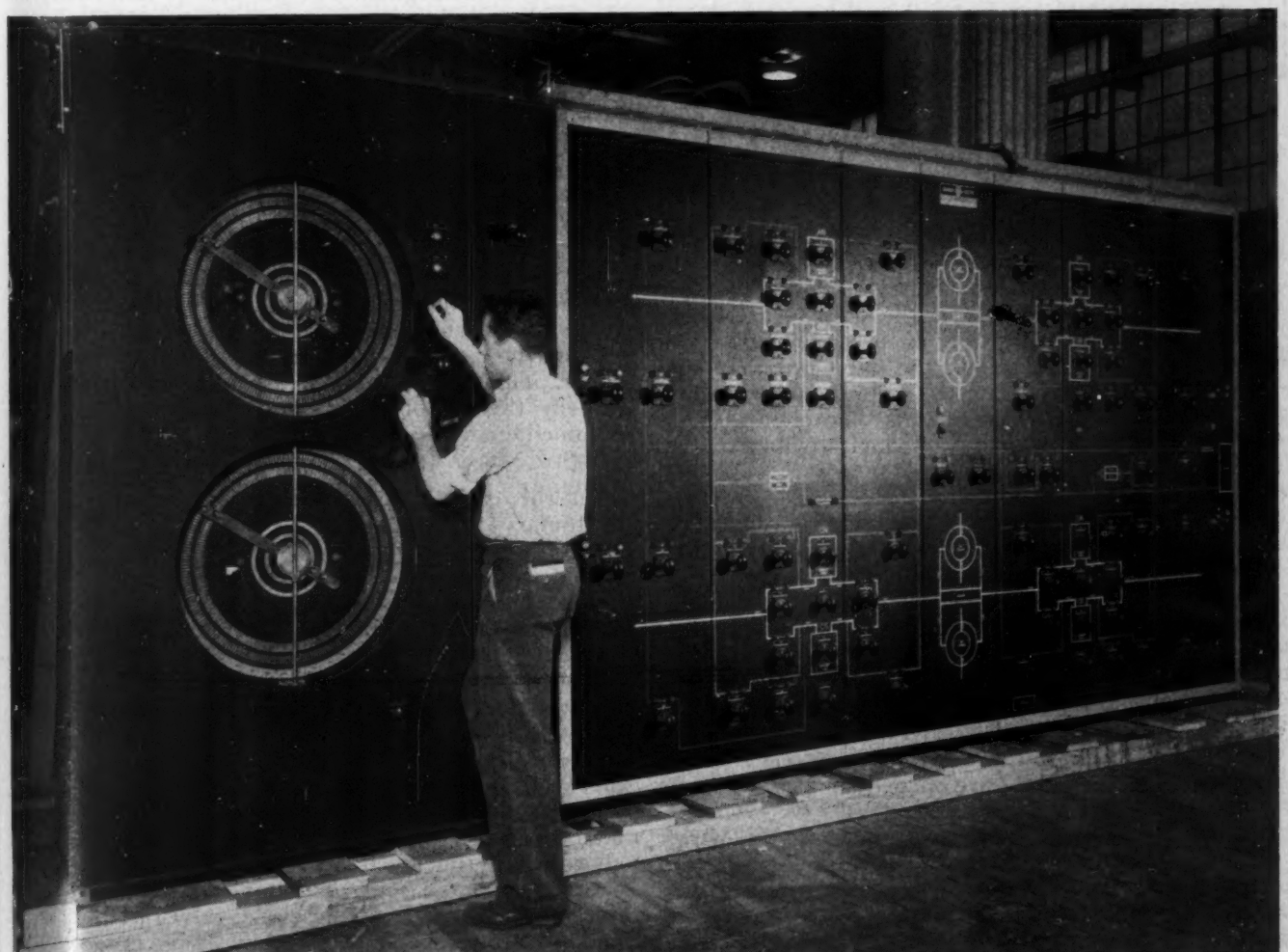


FIGURE 4

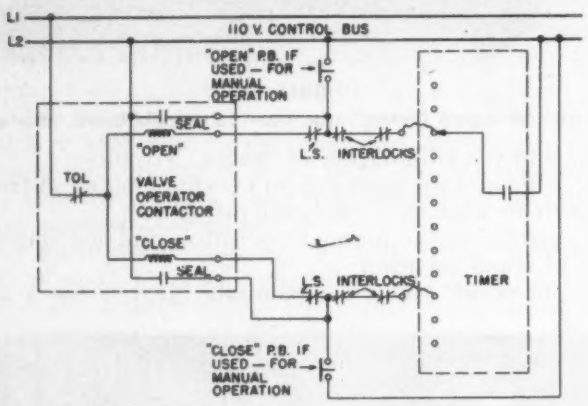
Two-dial "rotary timer" (left) integrally mounted with operator's control board, the latter containing valve position indicating lights, selector switches, and flow diagram.

minute cycle, will energize 6 points per minute, one point being energized every 10 seconds. Thus, a valve control plugged to point 40 and to point 160, will close (or open) the valve in 6 minutes, 40 seconds, from the start of the cycle; and will open (or close) the valve 20 minutes later, or 26 minutes, 40 seconds from the start of the cycle, assuming no dormant timer relay takes control in the interim.

How the Control System Works

Figure 5 shows schematically the basic method of control of motor-driven valves. Connections are shown to only one reversing contactor for a typical valve-operator motor. This sketch does not show connection of dormant timers, necessary auxiliary relays, alarm relays, etc., but is merely intended to illustrate the basic functioning of the equipment.

The operation is as follows. As the traveling arm of the timer moves from one segment of the timer to



Schematic showing basic method of control of motor-driven valve.

FIGURE 5

another, a synchronized auxiliary contact-making mechanism momentarily closes the circuit when the arm is in the middle of each button. Provided the interlock contacts—as shown in the sketch—are closed (indicating correct position of preceding valve or valves), the solenoid coil of the valve-operator contactor is energized, closing the contacts which establish a circuit to the valve-operator motor in a direction that causes this valve to start to open (or to close).

When this contactor closes, the circuit to the solenoid is established through the "seal" circuit, thus keeping the contactor closed after the momentary contact in the timer has been broken. The valve-operator motor will then be energized and will continue to operate until the valve has opened (or closed) causing limit switch (LS) on the valve to open. This breaks the circuit to the contactor solenoid, opening the contactor and shutting down the valve-operator motor.

As the timer continues to travel from one segment to the next, other valves are opened (or closed) in the same manner.

If, for any reason, the operator desires to operate the valves by hand control, a selector switch (not shown in the sketch) is thrown, transferring the control of the valves in a given section from the timer to control switches or push-buttons which may be manually operated to control any desired valve. This selector switch may either by-pass or retain the sequence interlock contacts, depending on process requirements. When the interlock contacts are by-passed, any valve can be opened or closed at any time, out of usual sequence and independent of the position of other valves. If sequence interlocks are retained in the circuit after the selector switch is thrown to "manual-control" position, valves can be hand-controlled only in the same sequence, and under the same conditions as to position of preceding valves, as when under timer control.

Other valves, not motor-operated, are opened or closed through solenoid-operated pilot valves which receive their impulses directly from the timer segments or through latched-in type relays, instead of through the valve-operator contactors.

The dormant or auxiliary timer, is a Telechron motor-driven time switch, with adjustable time settings ranging from 6 minutes maximum up to several hours maximum.

The function of the dormant timers is to shut down the main timer during relatively long periods when no valve operations are required. The master timer may be re-started when the dormant timer "times out" or by means of pressure switch or other auxiliary control means. This arrangement permits not only simplifications of the main timer by greatly reducing the required number of segments, but it also provides a means of changing the total period of the cycle. Additional means of changing the total period of the cycle is supplied by means of change gears for the master timer, so that the total period required to travel over the segments of the master timer may be changed, and the time per segment correspondingly changed.

The function of the interlocks is to prevent any given valve from being opened or closed unless the preceding valves are in the correct position. These interlocks may be either contacts in the limit switches integral with the valves, or contacts in a positioning relay, such as provided for use with the diaphragm valve.

If, for any reason, a given valve has not opened or closed at a desired time as indicated by the setting of the timer, an alarm relay functions to light a light or to give other audible or visible indications. If the user prefers, it may also function to shut down the main timer. This gives the operator an opportunity to remedy the trouble before the cycle of operation is resumed.

Conclusion

In the early days of catalytic cracking, it was customary for the process consultant or the contractor to secure, piecemeal, the timer, relays, individual valve-operator control units and other devices and then proceed to assemble and wire these components as an operating unit. Later, as requirements became more standardized and the advantages of factory coordination of equipment were realized, the unit construction illustrated in this article was widely adapted.

In the enormous expansion of this type of plant to meet war requirements, the experience which the electrical industry had gained from these earlier installations has made it possible to secure completely coordinated time-cycle valve control, with the user, contractor, or process consultant sometimes supplying only functional specifications, valve operator data, and operation sequence data, thus saving considerable time and effort on the part of his engineering and drafting departments and usually resulting in a more compact and reliable operating unit.

Determination of Tetraethyl Lead in Gasoline

LOUIS SCHWARTZ, Tide Water Associated Oil Company

THE production of maximum quantities of high-octance aircraft-engine fuels necessitates the use of tetraethyl lead to the top limits of the permissible tetraethyl lead content. To facilitate the commercial blending of gasolines to these top limits, an accurate and rapid method for the determination of tetraethyl lead is required.

The present ASTM method[1] and the nitric acid extraction method proposed by Baldeschwieler[2] require from 3 to 4 hours to complete a lead determination. The number of tests that can be run at one time by the ASTM method is also limited by the extractors available. The disadvantages of these and other proposed methods are the time required for extraction and the necessity of oxidizing organic matter which is extracted with the lead. The possibility of loss of lead in extraction at higher temperatures is recognized in provision for the use of a heavy solvent in the ASTM method.

This paper describes an extraction procedure and lead-determination methods which overcome the disadvantages of previous methods. The total time of test is usually less than one hour. Clean-cut separations in the extraction are obtained almost instantaneously, complete removal of the lead is effected within 8 minutes, and without further oxidation of organic matter the lead may be completely precipitated as chromate.

The method is a modification of Baldeschwieler's nitric acid extraction procedure,[2] replacing concentrated nitric acid with a 1.2 to 1 nitric acid solution saturated with potassium chlorate and containing a trace of copper nitrate. The extracted lead is determined by a volumetric oxidation-reduction reaction after precipitation as lead chromate.

Preparation of Extraction Solution

Measure 550 ml. of concentrated nitric acid (specific gravity 1.42) into a tall 1000-ml. G. G. S. cylinder, introduce 78 grams of potassium chlorate, stopper securely, and shake vigorously until most of the potassium chlorate is disolved. Add 450 ml. of water and shake again until solution is complete. Dissolve 0.1 gram of sheet copper in a small beaker with a minimum of nitric acid and evaporate to sirupy consistency. Dissolve the contents with a little of the extraction solution and rinse into the main portion. Mix until uniform. A solution so prepared will have a specific gravity of 1.30 at 21° C. (70° F.) and will contain approximately 40 percent of nitric acid by weight and 6 percent by weight of potassium chlorate.

PROCEDURE for the rapid determination of tetraethyl lead in gasoline, based on modifications of the Baldeschwieler[2] nitric acid method, is described. By using 40 percent nitric acid containing 6 percent potassium chlorate and a separatory funnel, complete extraction of the lead is effected in 8 minutes with clean-cut separations and negligible heat rise even with 100 percent cracked gasolines.

The amount of lead is determined in the extractions by either volumetric or gravimetric methods. When frequent determinations are to be made, a preferred columetric chromate method is recommended as more rapid than the gravimetric methods described.

Reprinted from *Industrial and Engineering Chemistry*, Analytical Editon, 15, 8, August, 1943.

NOTE—A private communication from W. M. Basch, Standard Oil Development Company, indicates that for gasolines rich in unsaturates better results were obtained in his laboratory by adding an excess of potassium chlorate to the nitric acid solution and allowing the mixture to stand approximately 5 to 7 days before using.

Procedure

Add 15 ml. of the nitric acid-potassium chlorate solution to 100 ml. of gasoline in a 500-ml. separatory funnel. Stopper securely and shake gently at first, releasing the pressure frequently, then shake more vigorously for 3 minutes until no further reaction is noticeable and the gasoline layer becomes perfectly clear. Allow to settle for 1 minute, then draw off the acid layer into a 500-ml. Erlenmeyer flask. Repeat the extraction twice, reducing the shaking periods to 1 minute.

From this point the lead may be determined by any standard procedure for lead determination, but methods permitting greater speed without sacrifice of accuracy are to be preferred. Descriptions of the volumetric and gravimetric chromate methods and of the lead sulfate method are presented because of modifications which speed up the determination and maintain its accuracy. This laboratory recommends the volumetric chromate method, when frequent determinations are necessary, as it is the most rapid.

Volumetric Determination as Chromate. Evaporate the combined extracts just to crystallization (do not take to complete dryness). Add about 100 ml. of hot water and heat to boiling. Allow to cool for a few seconds. Neutralize with ammonium hydroxide to the characteristic deep blue of the cuprammonium

compound and add 2 ml. in excess. Acidify with acetic acid and add 1 ml. in excess. Bring to a boil and add 10 ml. of 5-percent potassium dichromate solution. Digest on the hot plate for 7 minutes. Filter through a Gooch crucible and wash thoroughly with hot water, then with three portions of about 5 ml. each of acetone, followed by a similar ethyl ether wash to remove organic matter which may impede the subsequent solution of the precipitate. Dry for a few minutes at 100° C. until no odor of ether is noticeable.

Transfer the Gooch crucible to a clean 500-ml. suction flask. Dissolve the lead chromate, using suction, with 150 ml. of a solution obtained by adding 200 ml. of hydrochloric acid (specific gravity 1.19) and 350 ml. of water to 1 liter of filtered saturated commercial sodium chloride solution. Make up to 250 ml. with cold water. Introduce 2 grams of solid potassium iodide crystals, gently swirl the flask to dissolve the potassium iodide, and titrate the liberated iodine immediately with 0.04 *N* sodium thiosulfate solution until the yellow color due to the free iodine is very faint. Then add 2 ml. of starch solution and complete the titration to a clear green end point.

Gravimetric Determination as Chromate. Where gravimetric determination is desired, proceed as above through digestion on the hot plate. Filter through a tared Gooch crucible and wash thoroughly with hot water, then with three 5-ml. portions of acetone, followed by a similar ethyl ether wash. Dry for a few minutes at 100° C. until no odor of ether is noticeable. Cool and weigh.

Gravimetric Determination as Sulfate. If it is desired to determine the lead gravimetrically as lead sulfate, draw off the extract into a 400-ml. beaker instead of an Erlenmeyer flask, add 9 ml. of concentrated sulfuric acid to the combined extracts in the beaker, and evaporate to fumes on a hot plate. If any charring occurs add cautiously (one drop at a time to avoid spattering) concentrated nitric acid which is saturated with potassium chlorate until no trace of charring is observed when brought to copious fumes. Allow to cool, add about 5 ml. of cold water, and evaporate again to the fuming point. Allow to cool for about 2 minutes, add 70 ml. of lead acid,[3] and heat to boiling. The lead acid is a dilute sulfuric acid saturated with lead sulfate. Filter through a tared Gooch crucible as soon as the solution is cooled to room temperature. Wash thoroughly with the lead acid, then with three 5 ml. portions of acetone, followed by a similar ethyl ether wash. Dry for a few minutes at 100° C. until no odor of ether is noticeable. Weigh when cool.

Standard Lead Nitrate Solution

In the determination of lead by the volumetric chromate method it is customary to standardize the thiosulfate solution accurately against pure lead nitrate. The method used in this laboratory is as follows:

Dissolve 7.1808 grams of C. P. lead nitrate in water containing 5 ml. of nitric acid and make up to exactly 1 liter in a volumetric flask. For standardization of a sodium thiosulfate solution (preferably 0.04 *N*), pipet 25 ml. of the standard lead nitrate solution into a 500-ml. Erlenmeyer flask. Add 35 ml. of the nitric acid-potassium cholrate solution and evaporate to crystallization under a hood. Remove from the heat, add 100 ml. Erlenmeyer flask. Add 45 ml. of the nitric acid-for the volumetric determination.

On the basis of 100 ml. of gasoline taken for a test, 25.0 ml. of the standard lead nitrate solution are equivalent to 4.00 ml. of tetraethyl lead per gallon. The calculations would therefore be:

$$\text{Ml. of } Na_2S_2O_3 \times K = \text{ml. of tetraethyl lead per gallon}$$

$$\text{where } K = \frac{4.00}{\text{ml. of } Na_2S_2O_3}$$

The sodium thiosulfate solution should age for at least one week before standardization and should be checked about once each month.

Discussion

While 1.2 to 1 nitric acid solution saturated with potassium chlorate was found to be best suited to the average type of gasoline tested in this laboratory, stronger or weaker solutions may be more advantageous, depending upon the particular type of gasoline most frequently tested. When employing a stronger solution on straight-run gasolines the initial shaking period of 3 minutes can be reduced considerably. However, a concentration weaker than one volume of acid to one volume of water will necessitate a longer period for the first shaking. An 0.9 to 1 solution of nitric acid saturated with potassium chlorate will take about 10 minutes for the first shaking.

With 100-octane and similar gasolines, which are colored green or blue, the breaks between the gasoline and acid layer are so clean-cut that it is sometimes difficult to see the line of separation. In such cases it is advisable to add 1 drop of oil-soluble red dye. The red dye is stable, while the green and blue dyes fade.

TABLE 1

Time Required for Complete Extraction of Lead

	Time of Shaking Min.	Tetraethyl Lead Extracted Ml./Gal.
1st Shaking	3	3.76
2nd Shaking	1	0.18
3rd Shaking	1	0.01
4th Shaking	1	0.00*
Total	6	3.95

* Complete removal of lead was effected in three extractions on all samples tested.

The time required for complete decomposition and extraction has been determined on a sample of 100-octane gasoline containing 3.95 ml. of tetraethyl lead per gallon with results as shown in Table 1.

The time required for a completed lead determination has been reduced from 4 hours to less than 1 hour. The important contributing factors are:

1. The improved extraction method reduces the time for complete removal of the lead to 8 minutes as compared with 1 hour by the hydrochloric acid extraction or 15 hours by the Baldeschwieler method. Further time is saved, owing to the smaller volume of extract to evaporate (approximately 45 ml. in this method, 150 ml. in the hydrochloric acid method, and 80 ml. in the Baldeschwieler method).

2. The use of the thiosulfate titration eliminates the drying, ignition, and weighing of precipitates necessary in the usual gravimetric methods.

Time-saving is also apparent where this extraction method is used in conjunction with the modified gravimetric methods described. In the gravimetric chromate method, use of the acetone-ether washing eliminates the necessity of complete oxidation of organic matter and lessens the drying time. In the sulfate method, complete oxidation of all organic

matter is obtained more rapidly because of the potassium cholrate. The use of alcohol and one-hour settling in an ice bath is unnecessary when lead acid[3] is substituted for dilution and washing. The acetone-ether wash with drying at 100° C. replaces the ignition of the lead sulfate.

Table 2, typical of several hundred tests run in this laboratory, shows that accuracy and reproducibility have been maintained.

Safety of Potassium Chlorate in Dilute Nitric Acid

Potassium chlorate in dilute nitric acid solution can be used safely when extracting cracked gasolines; the actual temperature rise resulting is given in Table 3. The results obtained in this experiment indicate that the heat rise due to shaking a cracked gasoline with the extraction solution is not necessarily in direct proportion to the acid heat. In no case, however, is the heat so generated sufficient to interfere with the procedure.

Influence of Small Amounts of Copper

The small amount of copper added to the extraction solution serves as an indicator in neutralization. Analysis with known amounts of lead demonstrates the effect on accuracy. The results in Table 4 show that the small amount of copper added to the extraction solution does not interfere with the determination of lead in either the volumetric or gravimetric methods.

Influence of Ether and Acetone Washings on Accuracy

The influence of acetone and ethyl ether washings on the accuracy of results was determined (Table 5).

The acetone and ether washings not only speed up the test but are essential for accurate results both in the volumetric method and in the gravimetric methods when the lead is extracted from gasoline by the nitric acid-chlorate method. In the lead sulfate method, the actone removes all traces of the lead acid solution; in the lead chromate method, washing with acetone removes all traces of organic matter that otherwise would tend to give high results when weighed and low results when titrated because of incomplete solubility of the lead chromate in the hydrochloric acid used. After the lead chromate has been washed with acetone and ether and the ether expelled, the resulting lead chromate is completely soluble in hydrochloric acid solution.

Literature Cited

[1] Am. Soc. Testing Materials, Designation D526-42 (October, 1942).
[2] Baldeschwieler, E. L. Ind. Eng. Chem., Anal. Ed., 4, 101-2 (192).
[3] Scott, W. W., "Standard Methods of Chemical Analysis," 4th Ed., Vol. 2, p. 1044, New York, D. Van Nostrand Co., 1925.

TABLE 2

Typical Comparative Results

Gasoline	Acid Heat ° F.	Tetraethyl Lead by ASTM Method* Ml./Gal.	Tetraethyl Lead by Nitric Acid-Chlorate Method: Chromate Volumetric Ml./Gal.	Chromate Gravimetric Ml./Gal.	Sulfate Gravimetric Ml./Gal.
A	100	0.25	0.25	0.26	0.26
B	111	2.60	2.61	2.62	2.62
C	24	2.99	3.00	3.00	2.99
D	1	3.99	3.99	4.00	4.01
Average time for test, hours		3–4	0.5	0.75	1

* Extracted and weighed as lead, chromate in accordance with ASTM method.

TABLE 3

Heat Rise of Cracked Gasolines

Gasoline	Acid Heat ° F.	Gasoline Temperature Before Shaking ° F.	Gasoline Temperature After Shaking: After First Shaking ° F.	After Second Shaking ° F.	After Third Shaking ° F.
F*	120	60	70	70	70
G†	120	71	80	79	78
K‡	88	76	92	89	88
L§	97	75	91	88	84

* Unleaded catalytically cracked gasoline.
† Prepared by adding 3 ml. of tetraethyl lead per gallon to Gasoline F.
‡ Cracked gasoline, containing 0.54 ml. of tetraethyl lead per gallon.
§ Cracked gasoline, containing 2.98 ml. of tetraethyl lead per gallon.

TABLE 4

Influence of Small Amounts of Copper

Determination	Standard $Pb(NO_3)_2$ Equivalent to: Ml./Gal.	Results with Copper Indicator: Volumetric Chromate Method Ml./Gal.	Gravimetric Chromate Method Ml./Gal.	Gravimetric Sulfate Method Ml./Gal.
1	4.00	4.00	4.00	3.99
2	4.00	4.00	4.00	4.00

TABLE 5

Influence of Ethyl Ether and Acetone Washings on Accuracy of Results

Determined as	Tetraethyl Lead Present Ml./Gal.	Tetraethyl Lead Found: Without Acetone-Ether Wash Ml./Gal.	With Acetone-Ether Wash Ml./Gal.
Gasoline C			
$PbSO_4$	2.99	3.02	2.99
$PbCrO_4$ (gravimetric)	....	3.03	3.00
$PbCrO_4$ (volumetric)	....	2.91	3.00
Gasoline D			
$PbSO_4$	3.99	4.01	3.99
$PbCrO_4$ (gravimetric)	....	4.02	4.00
$PbCrO_4$ (volumetric)	....	3.93	3.99

Octane Number Nomographs

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Wyandotte Chemicals Corporation, Wyandotte, Michigan

AS SHOWN previously, the octane number of gasoline can be calculated from the A.P.I. gravity and the 10- and 90-percent points of the A.S.T.M. distillation. Plots of the octane number against functions of these variables have been presented. The relationships in question, for the second method of calculation[1] are, $N = 1698.7 - 126.11\ (3.5 \log {}^\circ\text{A.P.I.} + 2 \log t_{10} + 1.3 \log t_{90})$ for gasolines with octane numbers between 16 and 62, and $N = 1020.7 - 64.86\ (4 \log {}^\circ\text{A.P.I.} + 2 \log t_{10} + 1.3 \log t_{90})$ for gasolines

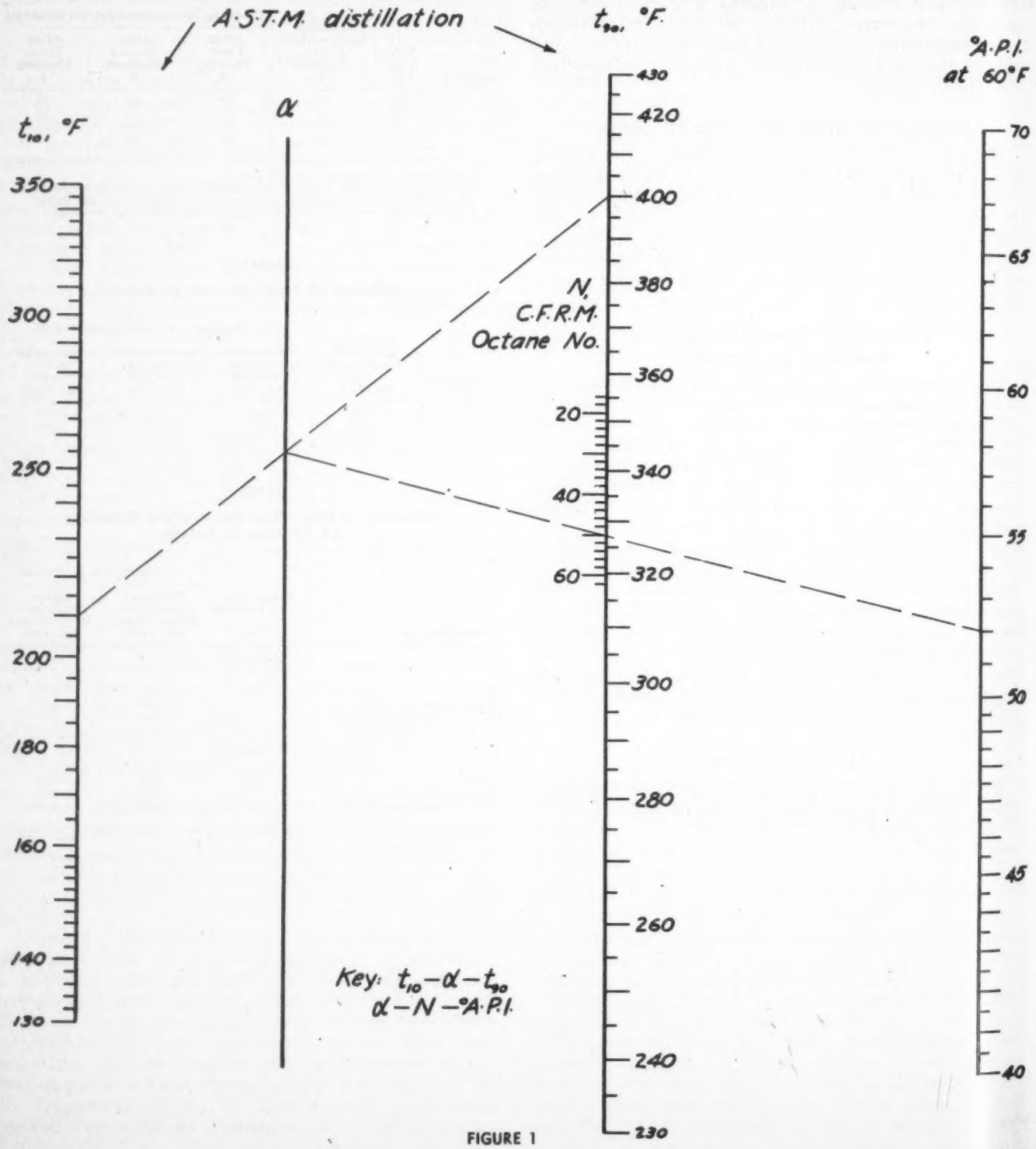

FIGURE 1

with octane numbers between 62 and 90, where N = C.F.R.M. octane number °A.P.I. = gravity corrected to 60° F., American Petroleum Institute scale, and t_{10} and t_{90} = the 10- and 90-percent points, respectively, of the A.S.T.M. distillation, °F.

The former charts require a somewhat tedious computation of the functions in the parentheses before they can be used. The accompanying nomographs, however, greatly facilitate the accurate calculation of octane numbers. Their use is illustrated as follows: What is the octane number when the 10- and 90-percent points of the A.S.T.M. distillation are 210 and 400° F., respectively, and the corrected A.P.I. gravity is 52 degrees? Using Figure 1 and following the key, connect 210 on the t_{10} scale with 400 on the t_{90} scale and mark the intersection with the α axis. Connect this point with 52 and the °A.P.I. scale and read the octane number on the N scale as 50. Figure 1 is used rather than Figure 2 since 400° F. does not appear on the t_{90} scale of the latter figure.

What is the octane number of a gasoline when the 10- and 90-percent points determined by an A.S.T.M. distillation are 175 and 365° F., respectively, and the A.P.I. gravity is 50 degrees? An attempt to use Figure 1 results in an intersection with the N axis which is beyond the scale, indicating that Figure 2, for higher values, should be used. As shown by the index lines on Figure 2 the octane number is 73.

The nomographs, constructed by methods previously described[2], yield octane numbers in satisfactory agreement with values read from the charts of the earlier paper and with experimental values.

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[1] Cox, R. B., Refiner and Natural Gasoline Manufacturer, 19, 31 (1940).

[2] Davis, D. S., "Empirical Equations and Nomography," Chaps. IV and V, 1st ed., McGraw-Hill Book Co., New York, 1943.

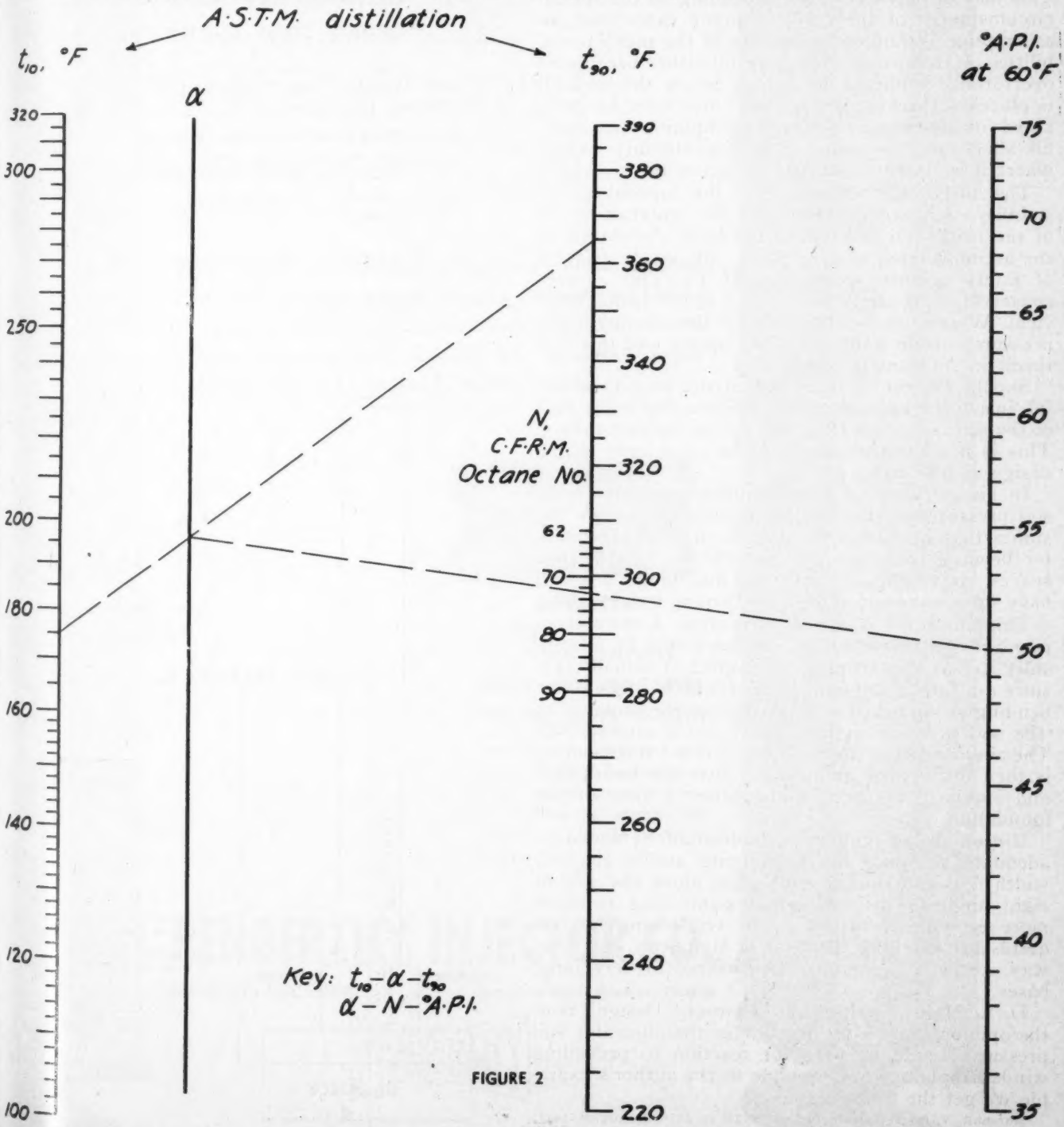


FIGURE 2

Notes on Design of Foundations For Stacks and Towers*

SAMUEL GARNETT

IN HIS determination of stability, the author counted on the earth back-fill as a stabilizing force. This may or may not be so, depending on the special circumstances of the case. In many cases such an assumption is dangerous because of the many possibilities of absence of such back-fill either because of overturning moments developing before the back-fill is placed or because the back-fill may later be excavated for pipe repair, etc. It is my opinion that back-fill should not be counted on for stability except where it is clearly a permanent part of the structure.

The author bases the size of the foundation for stability on his requirement that the center of action of the load shall fall within the kern. As shown in the accompanying sketch, No. 1, this yields a factor of safety against overturning of 4.1. This is over conservative, a safety factor of 2 to 2.5 being sufficient. Where the soil is good and the allowable soil pressure is from 4 to 5 Kips per square foot this will result in substantial saving.

Should the center of action of the load then not fall inside the kern, it would indicate that some part of the soil under the base will not be under pressure. This is not harmful but must be considered in the design of the base.

In his calculation of the bending moment of the soil pressure on the foundation slab the author assumes that the slab will have as its critical section for bending the plane a-b (sketch No. 2). He then spaces his reinforcing steel so that plane a-b will have sufficient reinforcing to withstand that bending.

This procedure is over conservative. A more accurate and still conservative method would be to consider A-B as the critical plane. Which it actually is—since a-b cannot fail unless the rest of A-B goes. The bending around A-B is derived from the moment of the soil pressure in the area A-B-f-g around A-B. The amount of reinforcing steel to resist this bending is then distributed uniformly across the width G-F and similarly in each of the other 3 axes of the foundation.

If economy of reinforcing is desirable it would be adequate to space the reinforcing across the full width A-B and similar reinforcing along the axis at right angles. This method of reinforcing is much more economical of weight of reinforcing but requires bar detailing. Because of simplicity, the four-way system is generally used except in very large bases.

D. A. Molitor writing on "Chimney Design" is of the opinion that only a fraction of the allowable soil pressure should be used for reaction to prevailing winds. Applying this principle to the author's example we get the following:

Permitting only 50 percent of allowable soil pressure for reaction to prevailing winds.

S 2p = Soil pressure due to prevailing winds.

$$\frac{S\,1}{S} + \frac{S\,2p}{.5\,S} = 1 \quad (12)$$

If force of prevailing wind equal 50 miles per hour or 12 pounds per square foot.

$$Pw = 12 \times 4.5 \times 54 = 3000 \text{ lbs.} \quad \text{(equation 8)}$$

$$Mf = 3000 \times 33 = 100{,}000 \text{ ft. lbs.} \quad \text{(equation 7)}$$

$$S\,2p = \frac{100{,}000}{248.5} = 401 \text{ lbs./sq. ft.}$$

$$\frac{1155}{2000} + \frac{401}{1000} = .577 + .401 = 978 < 1 \quad \text{(equation 12)}$$

which is satisfactory.

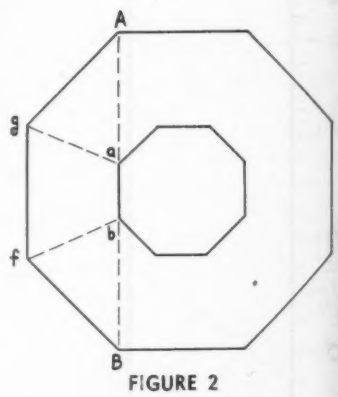


FIGURE 2

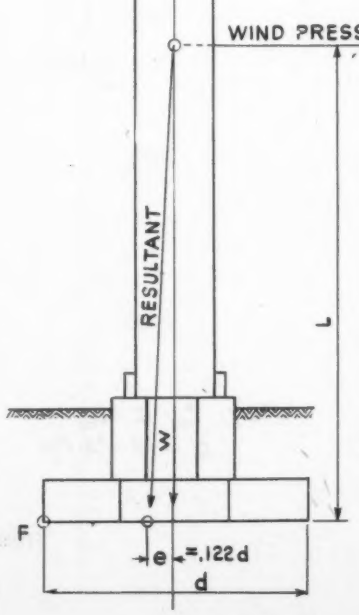


FIGURE 1

Considering Moments around F

$$\frac{Pw}{W} = \frac{e}{L}$$

$$PwL = We$$

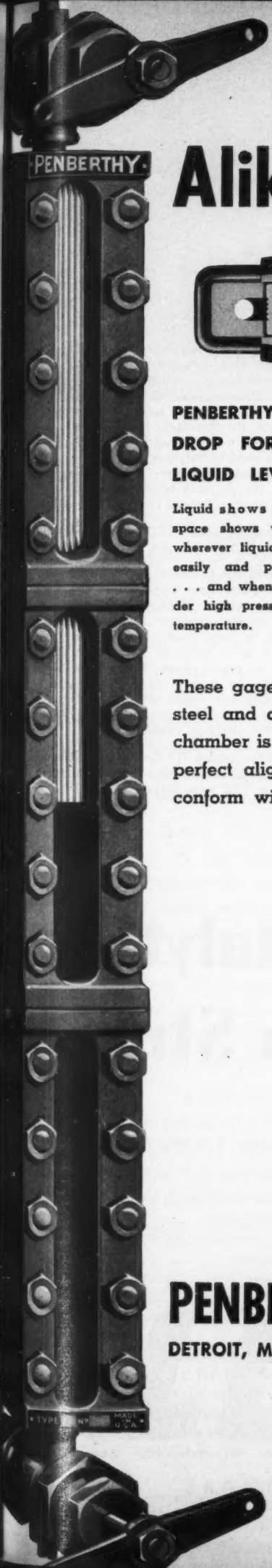
Overturning Moment
o.m. = PwL = We = .122Wd

Resisting Moment
R.M. = .5 Wd

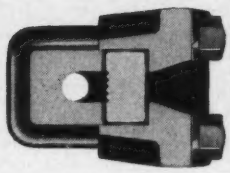
Factor of Safety

$$F.S. = \frac{R.M.}{o.m.} = \frac{.5wd}{.122Wd} = 4.1$$

*Marshall, V. O., Petroleum Refiner, 8, 22, pp 251-268, August, 1943.



Alike in Quality



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Liquid shows black — empty space shows white. Preferred wherever liquid level must be easily and positively visible . . . and when liquids are under high pressure or at high temperature.

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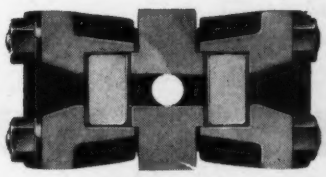

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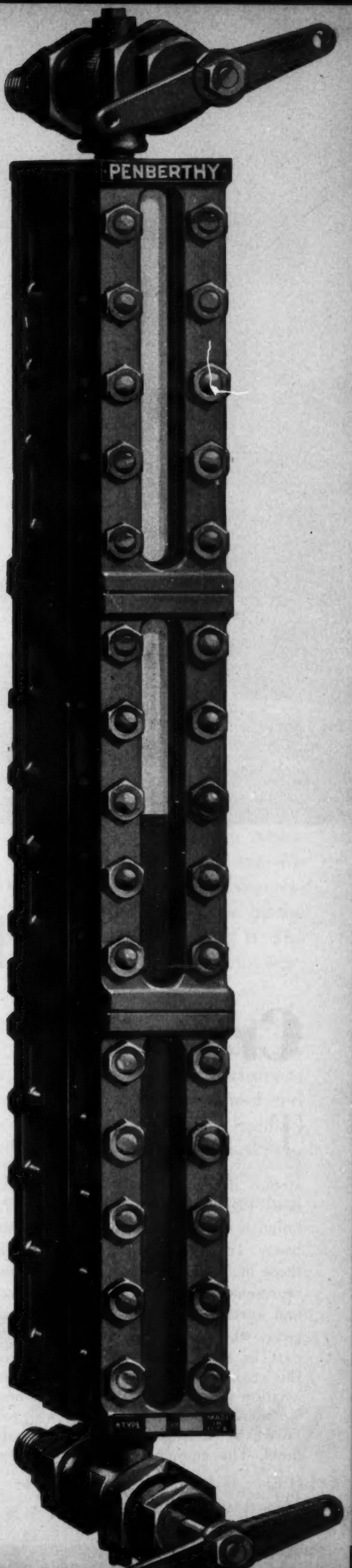

PENBERTHY INJECTOR CO.

DETROIT, MICHIGAN • **Canadian Plant; Windsor, Ontario**

PENBERTHY PRODUCTS

This TCC unit originally was designed to produce base stock for motor gasoline. When the need for 100-octane aviation gasoline became pressing, changes were made to permit operation that would provide substantial recovery of base stock for this fuel. Finally other design changes were incorporated to permit production of a high yield of butylene, to permit the Magnolia Petroleum Company plant to supply its share of charge stock to the nearby butadiene plant of Neches Butane Products Company.

There are 33 other TCC units building or under contract.

The Thermofor Catalytic Cracking process is the moving-bed type. Vapors from the furnace enter the bottom of the reactor and move counter current against the solid catalyst, which is in bead form. The catalyst moves downward at a speed of about one foot per minute. It passes from the bottom of the reactor to be picked up by elevators and carried into the regeneration chamber, where carbon is burned off and the renewed beads reenter the reaction chamber.

The Socony-Vacuum Oil Company technologists have invented a bead type catalyst, which will be used in TCC units later.

First Thermofor Catalytic Cracking Plant Put on Stream

THE first large-scale Thermofor Catalytic Cracking plant was put on stream at the Beaumont plant of Magnolia Petroleum Company October 11. Officials of Socony-Vacuum Oil Company, Inc., the parent organization, those of Magnolia Petroleum Company, representatives of the Army and Navy and executives of The Lummus Company, which constructed the unit, took part in ceremonies, which recognized this contribution to both 100-octane aviation gasoline and synthetic rubber.

An inspection of the plant was followed by luncheon at the Beaumont hotel. The equipment was brought on stream slowly. After 4 days it was operating at 60 percent of its rated throughput, 20,000 barrels daily. No difficulties had been encountered and engineers expected to have it at full capacity in less time than was anticipated.

This plant consisted of two Thermofor units, each of 10,000 barrels capacity, operating in parallel. The process can operate on either reduced crude or gasoil. It was started on reduced crude, which permits a charge of 26,000 barrels per day to be pumped into the furnace. Reduction permits withdrawal of 6,000 barrels of heavy fuel oil, leaving 10,000 barrels for each Thermofor unit.

Output from this charge is calculated to be:

	Barrels	Percent
Total charge	20,000	100
Coke, propane and lighter	980	4.9
Isobutane	660	3.3
Butylene	1,250	6.2
Normal butane	400	2.0
Aviation gasoline base stock	7,700	38.5
Furnace distillate	8,120	40.6
Heavy fuel oil	900	4.5

Recoveries of this order will permit half the output of the unit to be finished into products essential to the war effort.

The 400-end-point gasoline base

SYMBOLIC OF THE TRADE MARKS OF INDUSTRIAL AMERICA,

the monogram of Elliott Company typifies the engineering skill and productive capacity which is casting the shadow of defeat over Axis aspirations.

The total eclipse approaches

The war is now feeling the weight of one irresistible factor — the combined might of American manufacturers, whose thousands of production lines are disgorging the implements of mechanized battle in a volume almost unbelievable. *The trade marks of America are on the march.*

Every one of these thousands of trade marks represents a standard and type of engineering ingenuity peculiarly American, applied with an understanding of volume production and its possibilities far beyond that of any other people on earth. Each of them is the proud mark of successful individual enterprise, which here in America has come to its fullest fruition. *The trade marks of America are in the fight.*

The Axis powers do not know Production as we know it, nor did they realize the potentialities of American industrial organizations. Else they would not have chosen to start a mechanized war against, of all people, the nation which first introduced volume manufacturing, and whose mechanical ingenuity is supreme. The Axis lost the war at Pearl Harbor, unleashing for their own ultimate destruction the mighty forces of American individual enterprise. *The trade marks of America spell doom for the Axis.*

We believe the unified might of American management, American engineering, American labor, and notably of American individual enterprise, provides the most powerful single factor in the favorable course of the war, and that history will so record it. *The trade marks of America are winning the war.*

●

Elliott Company is one of those large manufacturing organizations whose products are of a basic type, equally vital and necessary in peace as in war. Elliott power equipment and Elliott process apparatus are today battling toward victory ashore and afloat, just as they will be working to produce the essentials of the greatly expanded scheme of living which will follow the day of victory.

star has been added to e Army-Navy "E" flags n by both the Jeanth and the Ridgway nts of Elliott Company.

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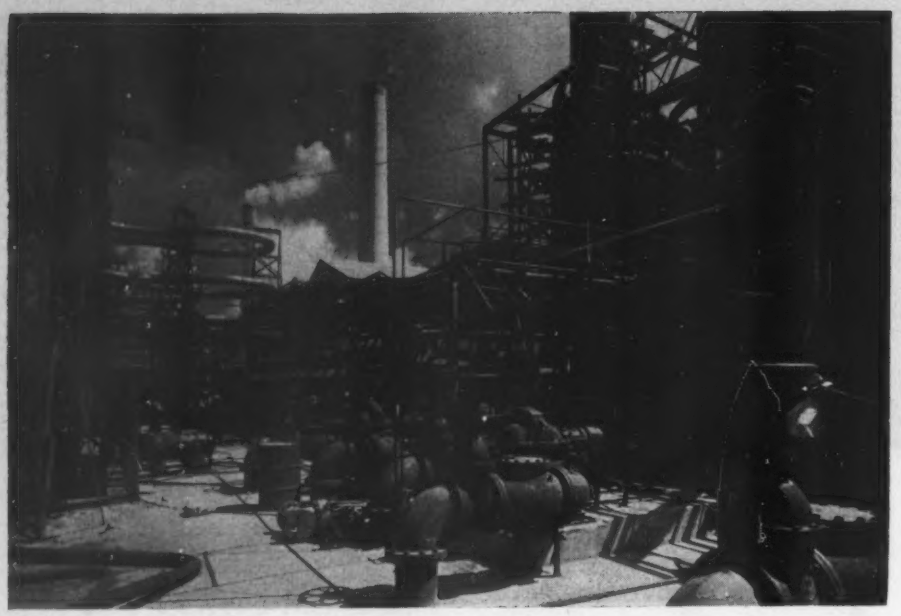

During Construction.

stocks, will after treatment be blended with alkylate, lead and other materials into 100-octane aviation gasoline. Isobutane and part of the butylene recovery will be charged to the alkylation unit. A part of the butylene also will be delivered to the nearby Neches Butane Products Company, which will contribute 100,000 tons of butadiene yearly to the synthetic-rubber program.

Magnolia Petroleum Company, The Pure Oil Company, The Texas Company, Gulf Oil Corporation and The Atlantic Refining Company formed the company which is completing this large butadiene unit and will provide raw charge for its operation. Other Thermofor units are under construction at The Pure Oil Company's plant at Nederland, Gulf Oil Corporation, Port Arthur, Crown Central Petroleum Corporation and Sinclair Refining Company, Houston. These with the two units operating at Beaumont make up 10 of the 35 Thermofor catalytic cracking units now under construction.

Before introducing speakers at the luncheon, John W. Newton, vice president of Magnolia Petroleum Company, pointed out that 4,000 persons from the Socony-Vacuum organization are now in the armed services and observed:

"May we be as good soldiers here as they are there."

The speakers were D. A. Little, president of Magnolia Petroleum Company, Dallas; A. F. Corwin, executive vice president of Socony-Vacuum Oil Company, New York; and Lieutenant Colonel John M. Fain, attached to the office of General H. H. Arnold, in charge of the training program.

Other officials of Socony-Vacuum Oil Company, who came to Beaumont for the affair were Wilbur F. Burt, director and member of the manufacturing committee; Dr. J. B. Rather, in charge of general laboratories of the company; George S. Dunham, vice president in charge of engineering; T. P. Simpson, a member of the manufacturing committee and one of the inventors of the TCC process.

Carl S. Reed, president, and E. R. Smoley, in charge of refining division of The Lummus Company, New York, represented the contracting firm.

Among the military personnel present were Colonel Walter H. Reid, commanding officer at Ellington Field; Lieutenant Colonel P. G. Bell, Eighth Service Command, petroleum division; Admiral Percy W. Foote, Houston, in charge of Navy construction in Texas.

The Thermofor Catalytic Cracking process (known as TCC) is a recent development, whose complete operating details can not be printed because of military secrecy requirements. It was briefly described in connection with putting this first plant on stream as follows:

"In the TCC process, developed by Socony-Vacuum Oil Company, the catalyst is not in a fixed bed but moves through the cracking chamber, passes out to be cleaned in a separate chamber and re-enters the cracking chamber in a continuous stream.

"In 1939 Socony-Vacuum Oil Company engineers developed the thermofor kiln for burning the carbon out of the clay used in the filtering of lubricating oil. Previously, the clay was cleaned by burning the carbon off in rotary kilns, which was expensive and wasteful, since much of the clay was lost. The thermofor kiln did the job much more efficiently. It got its name from "thermophore" which is a device for controlling heat.

"The kiln was adapted to the TCC process. A 500-barrel-a-day pilot plant was constructed at the Socony-Vacuum Oil Company laboratory at Paulsboro, New Jersey, where the process was tested and approved for more than 2½ years, during which further improvements were made.

"The catalyst flows by gravity from the top of the cracking chamber (called a reactor) against a rising stream of oil vapor, which enters at the bottom. The synthetic vapors created by the catalyst pass out at the top of the chamber to become cracked products; the catalyst passes out through the bottom. It is lifted by elevators to the top of the thermofor kiln or regenerator, where heat and air restore it to its former effetctive condition. It is then returned to the cracking chamber, to be re-used.

"The TCC process requires only moderate temperatures and pressures. The plant design is simple, and construction is relatively inexpensive. It may be installed in connection with existing thermal cracking units, thus reducing the investment required. Costs of operation are also lower. There is a substantial saving in steel and other critical materials. Because the TCC unit is as efficient in small size as in large, the small refiner may make use of it."

Safety Research Institute Gives Fire Prevention Tips

In the interest of refinery fire control during Fire Prevention Week, October 3-9, the Safety Research Society, 420 Lexington Avenue, New York, suggested special attention to the care of first-aid fire appliances.

"National preparedness and defense, and now wartime controls of materials, have required use of various substitute materials and methods, some of which may not be acceptable after victory, their replacement becoming a necessary part of the cost of war," is was said.

To keep equipment in good operating condition indefinitely, the society suggests that owners recharge extinguishers immediately after use and after the interval of time recommended by the manufacturer; use only recharging supplies and replacement parts obtained from the manufacturer; follow the instructions on units closely when recharging all types of extinguishers; inspect extinguishers at least once a month to be sure they are filled, operative and have not been tampered with; do not attempt repairs of damaged extinguishers—return them to the manufacturer for the skilled work such service demands; test an extinguisher that is damaged by a blow or fall to determine whether the shell or seam has been damaged; and have men on the premises who are familiar with the inspection and recharging of extinguishers, and who understand the correct methods for keeping the equipment ready for instant, efficient use.

NO. 9 OF A SERIES
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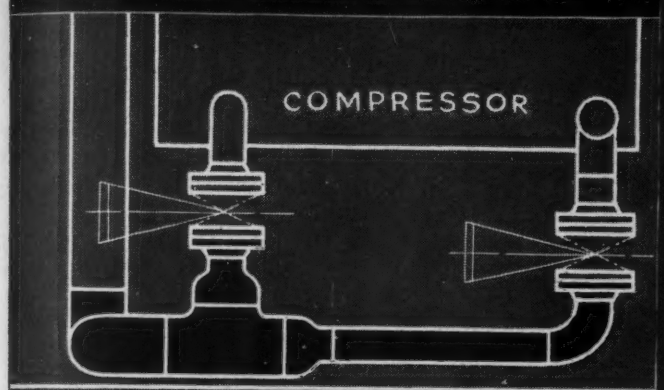

ELEVATION VIEW

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Petroleum Goes to War

BRUCE K. BROWN
Assistant Deputy Administrator, Petroleum Administration for War

An address delivered before the National Petroleum Association at its annual meeting in New York on September 22, 1943

I WANT to talk to you today of petroleum hydrocarbons but I promise that I shall not embark on a scientific discussion, nor shall I invoke any plea for greater production for war.

Science proceeds apace and, as I have told you before, I think almost every month that has passed since Pearl Harbor has induced a hot-house growth in technology as great as that which we experienced in a whole year of the last decade preceding the war. I could talk of that technology, but I shall not today.

I could implore each of you to re-evaluate your present operations in the petroleum industry to detect and correct any faltering in maximum production for war—for much yet remains to be done before it will be possible to evaluate today in the terms of a hoped-for peace in the tomorrow. You will be hearing more from the Petroleum Administration concerning maximum production of war products—but not today.

Today I would like to discuss petroleum hydrocarbons only from the standpoint of what is happening to them. That subject is one which is certainly of common interest to the petroleum industry, and to the Petroleum Administration. You and I are mutually distressed, I am sure, over the lack of appreciation on the part of our friends, our customers, and our masters —the American public—of the part that petroleum must play in winning this war.

Let us consider these petroleum hydrocarbons—refined products ready for use—on exactly the same basis as we now have to consider everything else —manpower, womenpower, food, textiles, metals, shipping and dollars. Let us consider how much of our petroleum products must go to war and how much can be retained for home use. Hydrocarbons drafted for war can't stay with us but the American public wants to know just what is becoming of those precious petroleum products upon which they have so long relied for their well-being, their comfort, and their pleasure.

Use in Other War

First of all, let us go back 25 years in order to get a good running start on our problem. During the first World War we refined and had available each day in the United States about 200,000 barrels of gasoline. We sent less than 37,000 barrels per day overseas at the peak of activity in 1918—less than 20 per cent of the total available. According to Captain Paul Foley[1] of our Navy, the total requirements of "aviation spirit" (the forerunner of our 100-octane aviation gasoline) by the United States, Great Britain, France and Italy for the last half of 1918 was scheduled at about 7,000 barrels per day.The United Nations in this war will be producing and burning that much aviation gasoline in the interval between this moment and the time I finish delivering this brief paper.

Oil was very important in the first World War and it seemed awfully important to civilians too. Prices rose and there were "gasless Sundays." As to the military importance of this oil this same Captain Foley said:

"Reviewed in the perspective of six years, it is clear that next to the physical number of bayonets on the Western Front, the factors contributing most to victory were the impetus conferred on those bayonets and the flexibility given them by gasoline. Tank, tractor and aviation activities all were measured in terms of gasoline. It evacuated the wounded and effected replacement of combat troops . . . Not in exaggeration was it said that a drop of petrol had been the equivalent of a drop of blood. The torch borne high on Flanders field was a gasoline torch."

More Important Now

But however important oil may have appeared to be to the civilian population in 1918, it was fully eight times as important in the year before we entered World War Number 2. In 1941 we used about 4,000,000 barrels of crude oil and natural gasoline in our refineries each day and made available to the public about 1,600,000 barrels of gasoline. Very little gasoline was consumed by the military. Very little aviation gasoline was consumed.

In the present month and for an undetermined future number of months, we hope to refine in this country about ten percent more crude oil and natural gasoline than in the pre-war era. Thus, it might be reasonably expected that we should have more gasoline available than ever before, and that assumption is correct. Gasoline production is currently about 1,800,000 barrels a day —that is all types of gasoline for all purposes.

"But"—the public says—"where is it?" "Why can't we use it?" "Why shortages?"

The answer is, of course, that petroleum is going to war. We know that. The public knows it. Unfortunately, however, the separation of petroleum from its normal associates, the civilian public, brings protests which to me seem more violent than any I have heard raised against sending other commodities to war. For this reason it is incumbent on us all to explain the situation patiently, again and again.

Statistics are uninteresting. The old adage "figures don't lie but liars figger" seems well forward in the public mind. Furthermore, the shroud of secrecy necessarily cast over overseas shipments of petroleum products and over present and ultimate productivity of critical war products, such as aviation gasoline and toluene, tends to confuse even the best informed. However difficult the task, it is necessary that we keep plugging, within the limits of military secrecy, at the job of telling and retelling the story of petroleum products in the war, because it is extremely important to public morale and to the standing of the oil industry that the story be well told and well understood.

What I have to present to you today is not a new set of statistics but merely a somewhat different way of telling the story. Instead of spreading numbers throughout my talk I shall give you all of the principal figures at once and then put them together in a way which, I trust, will bring out the story.

Restating the petroleum side of it, we are currently using each day about 4,400,000 barrels of crude oil and natural

[1] Captain Paul Foley "Petroleum Problems of World War" U.S. Naval Institute Proceedings, November, 1924.

THE MOTHER OF A...

"Rubber Plantation"

PRAISE the Lord . . . we're passing *plenty* of rubber!" Shall we soon be able to say that? Every day brings further proof that Axis treachery and conquest are no match for American ingenuity.

Using a unique process and depending mainly on existing equipment, the Southern California Gas Company will soon be adding 35,000 tons of butadiene per year to the nation's supply of synthetic rubber! This outstanding development is truly "a rubber plantation" in 1943 style!

Hand in hand with Southern Cal's ingenuity goes Cooper-Bessemer reliability. C-B compressors, Type G-MV, will be used in two phases of the process — for charging stock and for refrigeration.

It's another "world's first" for Cooper-Bessemer—another indication that where continuous, critical processing is imperative, broad flexibility . . . precise response to control . . . and engineered dependability are of the utmost importance. Type G-MV's are doing a real job in many of the nation's most vital plants.

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gasoline and we are turning it into about 3,800,000 barrels of products. The balance goes into refinery losses, refinery fuel, and crude export. The amount of crude exported is quite small and is diminishing. Out of these raw materials we produce each day about 1,800,000 barrels of gasoline and 2,000,000 barrels of all other products. The Petroleum Administrator recently stated that the military services had to be supplied with about 600,000 barrels per day of gasoline. High officials of the services recently stated that the total military demand for all petroleum products exceeded a million barrels a day. In this present month about 32 percent of all petroleum refined products are used by the military. The figure will rise to 40 percent before many months.

The above figures are all that are really needed to provide a base for an easily comprehended story of where our petroleum hydrocarbons are going.

But I have more figures to point up the story. None of them are secret and few are new.

In the halcyon days prior to Pearl Harbor, we had about 27,500,000 passenger automobiles. That number has now dropped to about 24,500,000.

Military Vehicles

No one would be foolish enough to think that because there are 11 percent less automobiles on the road, those that are left should have more gasoline than ever because everyone realizes that the automobile companies did not really stop producing automobiles. Instead of Chryslers, we have produced tanks; instead of Willys-Overlands, jeeps; and instead of Fords, aircraft engines, bombers, and the like. Among such little items, the President recently announced the production of 123,000 planes, 53,000 tanks, and 1,233,000 trucks. Those numbers will rise. Further, most of our citizens know instinctively that our military vehicles are greater "gas-eaters" than civilian automobiles and trucks. They are more powerfully motored; they are bigger; they go faster; they go farther. The comparison is particularly striking in the case of automobiles and planes. In one hour's travel at the legal speed of 35 miles per hour, a passenger automobile will burn about 2.5 gallons of gasoline. But a fighter plane will travel ten times as far in an hour and will burn about 60 gallons of gasoline. Our great bombers use several times that much. That part of the story has been told before, told better, and with more ililustrations. The telling of it has allayed some protests but we all know that the motorist is far from convinced. If he accepts such explanations, he does it to be a good sport—not because he is completely satisfied.

A very considerable part of our available food stuffs have to be diverted to military use at home and overseas.

Why is it then, that our friends, our customers, and our masters—the great American public—submit so patriotically to short rations on some foods and, at the same time, seem critical of any shortness in petroleum supply?

The need for food is universal and universally recognized. Within narrow limits rich man, poor man, soldier, civilian, American, Briton, Chinese, Russian, Frenchman or Italian can and does, if it is available, consume about the same amount of food stuffs. Our people are inherently generous and they do not really contest the need for allotting 30 percent or more of our available food to military and overseas use. Why, then, is it so difficult to explain that 30 to 40 percent of petroleum must likewise be employed?

Of course, there is one small difference which we note immediately. In the case of food, no one attempts to influence the citizen to protest. Fortunately, our states have not taxed the consumption of food and, hence, the shortening of civilian consumption in the states does not affect tax revenues so directly as a shortening in the civilian consumption of gasoline. Further, there are no organized societies or associations of food eaters whose welfare depends upon a continuous availability of ample quantities of prunes or beans or whose officials rise up and denounce the food administration or the food industry because a storm ruins a peach crop or because water wells run dry.

However, I do not think that outside stimulation accounts for any considerable part of the honest perplexity which we note in the minds of our friends, as to the shortness of petroleum supply. I have another theory about it and I can best introduce it by suggesting a possible analogy in the field of food.

As I have previously stated, it looks as though we civilians could make use of 67 percent of the pork available and 50 percent of the raisins. We now have almost 67 percent of the gasoline still available to us and I doubt that we will ever have to get along with less than 50 percent—the same as our "current raisin ration," to make a bad pun.

Other Uses

Let us suppose, however, that in addition to eating raisins, we civilians used raisins as a raw material to make plastic articles and suppose, further, that the essential demand for plastic articles was such as to require one quarter of the whole raisin crop. In such a case the diversion of 50 percent of the raisin crop to the military and the continued use of 25 percent for a civilian purpose, that is making plastics, would let us have only one third of our normal peacetime ration of raisins for dietary purposes—not one half.

Applying this analogy to petroleum supply, I think we can discover the missing chapter in the story which we simply must make our citizens understand. To the pre-war passenger car driver, gasoline was something to be bought at the corner pump. He bought it in company with his peers and fellows. Trucks, buses, taxis, municipal cars and farm tractors did not block the entrance of the station driveway. The auto driver was hardly conscious of the non-passenger car use of gasoline. Had there been a serious and mysterious shortage of gasoline in some area and had all of those other vehicles piled into the service station driveway, the average American motorist would have graciously admitted that those other vehicles needed gasoline worse than he did. It is late in the game to point that out to him now but it must be done.

Reverting to the approximately 1,800,000 barrels of gasoline which we produce every day, only a small proportion can safely be used by civilian passenger automobiles. As stated by Petroleum Administrator Ickes, the daily military demands already are at the rate of 600,000 barrels. That leaves 1,200,000 barrels. Exhaustive surveys indicate that trucks, buses, and taxis simply must have 450,000 barrels each day. Failure to provide it would mean a breakdown in essential public transportation services. That leaves 750,000 daily barrels of gasoline to be divided between industrial use, farm use, and civilian passenger automobiles. It should be obvious to all that non-essential industries have been pretty much discouraged by lack of priorities for raw materials and by manpower problems so it is not asking too much to urge confidence in the idea that there is little waste of gasoline in present industrial use. The farm situation speaks for itself.

And so—there it is. We have only so much gasoline and it must be divided up. The ever-expanding military use is easily understood and cannot be criticized. But it is a serious mistake to assume that all that is left is available for A, B and C coupons. When that individual who never purchased his gasoline except at a service station erected for his express convenience is brought to realize that there was always—even in peacetime—and still is a tremendous consumption of gasoline by trucks, buses, taxis, tractors and farm equipment which is just as vital to his welfare as convenient personal transportation, we shall have gone a long way toward winning him to the view that petroleum is going to war.

War Theme Dominates API Program For Second Consecutive Year

FOR the second consecutive year the role of the petroleum industry in war will be the theme of the program of the annual meeting of the American Petroleum Institute, the Palmer House, Chicago, November 8 to 11, 1943. To the extent that censorship will permit, both general sessions and those of the Division of Refining will review accomplishments in the light of military necessity as well as anticipate what the future promises.

There will be three general sessions, one the afternoon of November 10, one that evening and one the afternoon of November 11.

The Division of Refining will have sessions the afternoon of November 9, the morning of November 10, the morning of November 11, all in the grand ball room.

An estimate of the program from the October API Quarterly was:

"At this second wartime convention of the petroleum industry high ranking Army, Navy and Coast Guard officers and executives from the Petroleum Administration for War, the War Production Board and other government agencies, as well as the new national commander of the American Legion will join oil men in reporting on the state of the nation with respect to petroleum in war. Speakers at two general sessions and at most of the nine group sessions will review what has already been accomplished and will outline what must still be done in the days ahead before victory.

"Petroleum Administrator for War, Harold L. Ickes, will address the second general session on Tuesday afternoon, November 11;

"The first general session, Wednesday afternoon, November 10, will hear Ralph K. Davies, deputy PAW administrator; Bradley Dewey, rubber director, and Warren H. Atherton, national commander of the American Legion. William R. Boyd, Jr., will give the annual address of the president at this session.

"A group session on wartime protection of petroleum facilities, including employee training, fire protection safeguarding of wharves and piers and internal security, November 9, will be addressed by A. A. Jergin, PAW, Captain Norman B. Hall, U. S. Coast Guard and Colonel George K. Engelhart, Provost Marshal General's Office.

"Three refining group sessions will consider wartime refinery cooperation and technologic team work between petroleum refiners and the Petroleum Administration for War and the Petroleum Industry War Council, as well as recent developments in research and in catalytic cracking. These sessions will have papers on cracking coil tubes in war plants, the role of the analytical chemist in war and the activities of advisory committees working on problems of aviation gasoline and lubricating oils for our war machines.

"One refining session will consider reports on two of the institute's projects in fundamental research: hydrocarbons in the gasoline fraction of seven representative crude oils; and synthesis and properties of hydrocarbons of high molecular weight. This session also will hear about the Houdry Adiabatic process for conversion of petroleum hydrocarbons and will conclude with a paper on cracking with catalysts. One session will be devoted to catalytic cracking."

During the week there will be meetings of the 50 standing and special committees. The board of directors will meet November 10 and its executive committee will meet the next morning.

The preliminary program for the Division of Refining follows:

TUESDAY, NOVEMBER 9

Wartime Cooperation:

Presiding: G. G. Oberfell, Phillips Petroleum Company, Bartlesville, Oklahoma.

Technological Teamwork.

T. G. Delbridge, chairman, PIWC Technical Advisory Committee, The Atlantic Refining Company, Philadelphia.

Cracking-Coil Tubes at War—They Can Take It.

P. J. Harrington, M. S. Northrup, and C. O. Rhys, Sr., Standard Oil Development Company, Elizabeth, New Jersey.

The Analytical Chemist on the Spot.

Harry Levin, chairman, PIWC TAC Subcommittee on Analytical Methods, The Texas Company, Beacon, New Jersey.

The Activities of the Aviation-Gasoline Advisory Committee.

H. G. Burgs, Jr., chairman, PAW Aviation-Gasoline Advisory Committee, Standard Oil Company of New Jersey, New York.

Oiling the War Machine.

G. R. Lord, chairman, PAW Lubricating-Oil Advisory Committee, Sinclair Refining Company, New York.

The Coordinating Research Council.

K. G. Mackenzie, chairman, Automotive Research Committee, The Texas Company, New York.

WEDNESDAY, NOVEMBER 10

Research Reports and Catalytic Cracking:

Presiding: J. F. M. Taylor, Shell Oil Company, New York.

Hydrocarbons in the Gasoline Fraction of 7 Representative Crudes, Including All the Distillates 40 to 102° C. and the Aromatics to 160° C.

A. F. Forziata, C. B. Willingham, B. J. Mair, and F. D. Rossini, National Bureau of Standards, Washington.

The Synthesis and Properties of Hydrocarbons of High Molecular Weight—III.

R. W. Schiessler, D. G. Clarke, C. S. Rowland, W. S. Sloatman, and C. H. Herr, The Pennsylvania State College.

Houdry Adiabatic Process for the Conversion of Petroleum Hydrocarbons.

Eugene J. Houdry, Houdry Process Corporation, Wilmington, Delaware.

Cracking with Catalysts.

C. L. Thomas, N. K. Anderson, H. A. Becker, and J. McAfee, Universal Oil Products Company, Chicago.

THURSDAY, NOVEMBER 11

Catalytic Cracking:

Presiding: W. B. Ross, The Pure Oil Company, Chicago.

Gas-Oil Cracking by the Cycloversion Process.

W. A. Schulze and C. J. Helmers, Phillips Petroleum Company, Bartlesville, Oklahoma.

Recent Developments in TCC Processing.

T. P. Simpson, J. W. Payne, L. P. Evans, and C. V. Hornberg, Socony-Vacuum Oil Company, Paulsboro, New Jersey.

New Houdry Static-Bed Developments.

R. H. Newton and T. B. Pickett, Houdry Process Corporation.

Fluid-Catalyst Cracking for Premium Fuels.

E. V. Murphree, H. G. M. Fischer, E. J. Gohr, and W. J. Sweeney, Standard Oil Development Company, Elizabeth, New Jersey, and C. L. Brown, Standard Oil Company of Louisiana, Baton Rouge.

Report of Division's Nominating Committee.

J. T. McCoy, Tide Water Associated Oil Company, Bayonne, New Jersey, chairman.

Election of Twenty Members of the General Committee of the Division of Refining.

National Petroleum Association Reviews Oil in War Program

Contributions of the petroleum industry to war and its prospects after the war had consideration at the forty-first annual meeting of the National Petroleum Association, Waldorf-Astor Hotel, New York, September 21 and 22. Two considerations of economics of the industry were presented, that of crude oil by Joseph E. Pogue, Chase National Bank, New York; that of refined products by Bruce K. Brown, Assistant Deputy Petroleum Administrator, Washington. Contributions of scientific development were outlined by Gustav Egloff, director of research for Universal Oil Products Company, Chicago.

All officials of the association were reelected as follows:

H. A. Logan, president; Walter Reitz, J. B. Fisher and W. S. Zehrung, vice presidents; Fayette B. Dow, general counsel; Herbert G. Eaton, recording secretary; G. B. Hunter, treasurer.

The annual address of the president, H. A. Logan, was devoted largely to a consideration of prospects of the industry after the war. He drew a parallel between two World Wars, citing the fact that governmental agencies were dispensed with after the victory in 1918 as an indication that similar action would be taken at the end of World War II.

J. B. Fisher, association vice president, laid stress on the advisibility of keeping independent concerns active in the petroleum industry. He urged executives of the independent concerns to continue to conduct their affairs along conservative lines.

Gustav Egloff gave a summary of the several processes which have contributed to 100-octane gasoline and gave his estimate of the value of each in the program. Of the several processes, the one he designated as certain to remain as a factor in post-war refining is catalytic cracking. It drew this estimate because it increases the quality of gasoline as well as the yield of lighter products from crude oil.

Bruce K. Brown used current statistics to prove that a shortage of motor gasoline is a normal result of current refinery operations and military requirements. His figures were that 1,800,000 barrels of motor fuel are being made daily; that 600,000 barrels go into military use; that 450,000 barrels are required for transportation, leaving but $750,000 barrels for farm, industrial and civilian uses.

An increase in the price of crude oil was proposed by H. W. Dodge, director in charge of PAW District I, who analyzed the problems of production, refining transportation and marketing.

Two association departments held sessions. The program of the department of manufacture consisted of a paper, "Base Oil Evaluation for Heavy Duty Service," by A. O. Willey, Lubri-Zol Corporation, Cleveland.

The program for the department of traffic and transportation was devoted to a discussion of tank-car, tank-truck and pipe-line problems, under the chairmanship of S. F. Niness. R. W. Schields spoke on this program.

Lieutenant Colonel Keith L. Morgan spoke on "The War, the Army and You," and gave the association an estimate of how petroleum products serve in military operations.

John I. Yellott to Direct Institute of Gas Technology

John I. Yellott was appointed full-time director of the Institute of Gas Technology at Illinois Institute of Technology and assumed the duties of his new position September 1. He succeeds Harold Vatborg who will henceforth devote all his time to his duties as director of the Armour Research Foundation's industrial research program. Yellott also will assume the duties of directing the educational program of the Gas Institute, since Dr. Lincoln R. Thiesmayer, former educational director, resigned to enter government service.

Yellott has been chairman of Illinois Institute of Technology mechanical engineering department for the past three years and became director of the war training program in its first year in 1941. For this service he was cited by the Chicago Junior Chamber of Commerce as the outstanding young man of Chicago for 1942 and given its distinguished service award, and by the Illinois Junior Chamber of Commerce as the outstanding young man of Illinois for 1942 with the Illinois Civic Service Award.

An honor graduate in mechanical engineering of Johns Hopkins University, Yellott formerly was chairman of mechanical engineering at Stevens Institute of Technology and a member of the mechanical engineering faculty at the University of Rochester. He has also served as an industrial consultant in power and steam flow. In 1939 he was named the outstanding mechanical engineer of the past decade by Pi Tau Sigma, honorary mechanical engineering fraternity.

J. I. Yellott

Yellott's war-training program, in which more than 36,000 have been trained, is the largest in the nation in a single city and at a privately-operated college. As head of this program, he helped organize an explosives safety school for the office of chief of ordnance, United States War Department.

Allen Heads Information Department of API

Robert E. Allen is the director of the department of information set up by the American Petroleum Institute. Allen assumed his duties at New York headquarters in September. He resigned as assistant deputy administrator of the Petroleum Administration for War to accept the new position.

Allen was among the first men to enter government service when the original agency, Office of Petroleum Coordinator, was designated. He became director of production in June, 1941. In January of the next year he was made assistant deputy administrator.

Robert E. Allen

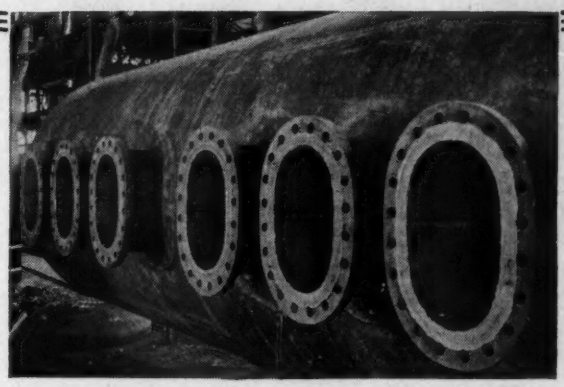
Before going to Washington he was chairman of the Alberta (Canada), Petroleum Conservation Board, and previously had held a number of important posts in the industry and on governmental agencies.

Both Ickes and Davies expressed regret over Allen's resignation and voiced appreciation of his two years work.

"Mr. Allen's new position as director of information for the API is a responsible and important one, particularly now when it is so necessary that the complete and accurate war story of petroleum be told," Ickes said. "As much as we regret losing his services, I am sure that he will continue to contribute very real assistance to the successful prosecution of the war from the petroleum standpoint."

Characterizing Allen as "one of the hardest working and most versatile members" of PAW, Davies pointed out

RESISTS CORROSION AT ALL POINTS OF CONTACT



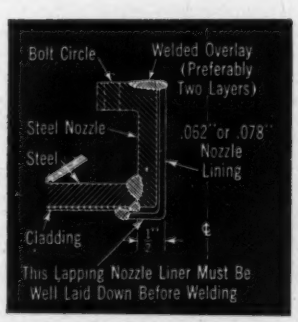
Fractionating tower, fabricated by Edge Moor Iron Wks., Inc. Diameter 6', overall length 43'6", top 15'6", section of Monel-clad 22/32" plate, cladding ⅛". Manways and covers also lined with ⅛" Monel, plug welded.

IN many important applications, the overlaying of Monel on steel permits maintaining continuous corrosion-resistant surfaces.

For example, in fabricating this fractionating tower of Lukens Monel-Clad steel plate, it enabled the manufacturer to protect the steel flanges with corrosion-resisting Monel. Thus, every part of the equipment which comes into contact with the harsh distillates resists their corrosive action.

Steel flanges are overlaid with Monel, first, by undercutting them 5/32" to 3/16" for a width of 1" or more, depending on the size of flange involved.

The first weld layer is deposited with ⅛" or 5/32" dia. No. 130X Monel electrode using string beads. Weaving is to be avoided because this technique makes a larger weld puddle . . . permits a higher percentage of iron to be diffused into the weld metal . . . lowers its corrosion resistance. Similarly, excessive penetration should also be avoided.



Suggested joint design, nozzle lining to sheet lining overlaying flange faces.

All flux should be removed from the first layer before depositing. Subsequent layers which may be laid down with a weave to produce beads up to ½" wide. Larger electrodes, $\frac{3}{16}$" or ¼", may now be used.

Monel overlays made with No. 130X electrodes on mild steel have a hardness of 150 to 160 Brinell (3000 kg.).

For full information on welding Monel, write for Bulletin T-2, "Welding, Brazing and Soft Soldering of Monel, Nickel and Inconel." The International Nickel Company, Inc., 67 Wall Street, New York, N. Y.

★ ★ ★ ★ **INCO NICKEL ALLOYS** ★ ★ ★ ★

MONEL • "K" MONEL • "S" MONEL • "R" MONEL • "KR" MONEL • INCONEL • NICKEL • "Z" NICKEL

Sheet . . . Strip . . . Rod . . . Tubing . . . Wire . . . Castings

that as assistant deputy administrator he bore a heavy load in the supervision of a number of the divisions as well as many additional duties, such as the chairmanship of staff committees and the liaison with several other government agencies.

"The more than two years during which he has given all of his energies to government services, almost invariably for seven days a week, were a conspicuous example of war sacrifice," Davies said. "His ability, personality and long experience in the oil industry should fit him to do a magnificent job for the Institute. I, personally, will miss him very much."

Carringer Is Promoted by Standard of New Jersey

J. R.. Carringer, general manager of manufacturing of Standard Oil Company of New Jersey, has been elected vice president. He will continue his direction of manufacturing operations of this major operating subsidiary of Standard Oil Company (New Jersey).

His complete business career has been with Standard Oil interests. His first work was in the tank car shop of Standard Oil Company (Indiana) at Whiting in 1903. In 1918 he came to the Bayway plant of Standard Oil Company of New Jersey as assistant general superintendent. He was promoted to assistant general manager of the three refining plants in 1936 and became a director of the company four years later.

Harry G. Burks, assistant to Chester F. Smith, president of the operating company, has been elected a director. He has been in the organization since 1924, following his graduation from Massachusetts Institute of Technology. In 1936 he became manager of the technical service division of the operating unit as well as technical advisor to the vice president in charge of manufacturing. In 1940 he became assistant to the president of the company.

J. W. Connolly, coordinator of the marketing division, also has been elected a director.

J. R. Carringer

Federal Court Denies OPA Business Suspension Right

A two-week suspension of Good Luck Oil Company, Dallas marketer, ordered by an OPA hearing commissioner last May, because the company accepted 1943 basic A rationing coupons before their effective date, has been ruled unconstitutional by Federal Judge William H. Atwell. An immediate appeal is planned by OPA.

Judge Atwell said there was no doubt Congress validly gave the President authority to allocate any material or facilities to promote national defense, and therefore that OPA had the right to ration commodities, but held that Congress had not delegated any power for OPA to suspend violators.

"The Congress," stated Atwell, "did not vest in the defendants (officials of OPA) such a power as here exhibited. If it did, it presumed to act improperly, which presumption will not be divulged. We must find that it acted constitutionally if possible, and lay the blame where it belongs—on the board.

"The hearing administrator unknown to and unprovided for by the Congress, presumes to conduct a court. Procedure is prescribed by his superior for such conducting. He enters a judgment concerning which there is no limit fixed. No maximum. No minimum.

"He acts without fear of consequences for malfeasance or misfeasance. If he can suspend for two weeks, he can suspend for two years. He not only is unknown to the Congress but he is unknown to the Constitution. Such power is vested in one Supreme Court and in such inferior courts as Congress from time to time may ordain and establish."

Judge Atwell added that as a result of the delegation of authority for allocation because of the declaration of war, there was conceived and born a hearing administrator who is and was without constitutional father or mother.

"No attempt at baptism in the waters of conflict can change his parentage and make it legitimate.

"This view of a penalty or punishment is sustained by a further reading of the allocation act which provides for the criminal punishment of a citizen who violates its provisions and also for equitable restraints, both of which take place in named courts."

Douglas L. Hooker in New Socony-Vacuum Post

Douglas L. Hooker has been appointed as a member of the manufacturing committee of Socony-Vacuum Oil Company. In this position he will supervise Eastern refining operations of the company and after the war will have charge of foreign refining operations.

His advancement from the managership of the Paulsboro, New Jersey, plant was to take the place of J. F. McElfresh, who died in August.

Hooker was born at Olean, New York. His college work at Cornell was interrupted by enlistment in the Navy in 1917. He was an ensign at the end of World War I and returned to Cornell where he was graduated in 1921 with a degree in mechanical engineering.

He joined Standard Oil Company of California as a process engineer in 1921. In 1929 he came to Vacuum Oil Company as an engineering specialist and after one year at the Olean plant went to Paulsboro, where he became assistant superintendent in 1931. Three years later he was promoted to superintendent and upon the retirement of C. J. Hamra in 1937 became manager at Paulsboro.

D. L. Hooker

H. W. Sheldon has been appointed manager of the Paulsboro plant. A. A. Neff has been advanced to superintendent and W. T. Furey has been appointed assistant superintendent.

AGA Meeting Postponed Until October 27-28

Because the St. Louis Cardinals won the National League pennant and a starting post in the world series, hotels of the city were too crowded to permit holding the annual meeting of the American Association there October 11, 12 and 13.

The meeting will be held October 26, 27 and 28 instead.

Wagner Again Secretary Of ACS Petroleum Section

C. R. Wagner was elected secretary of the Division of Petroleum Chemistry, American Chemical Society, at the annual meeting in Pittsburgh, September 12. Wagner relinquished the post when he left The Pure Oil Company to become a consultant with the Petroleum Administration for War.

He was succeeded by L. M. Henderson, also with The Pure Oil Company, Chicago.

Other officials were reelected as follows: C. L. Brown, chairman; R. E. Burk, vice chairman; S. S. Kurtz and D. E. Carr, members of the executive committee.

Stoll Refining Company Head Died on September 5

Charles C. Stoll, president and founder of Stoll Oil Refining Company, died in Louisville, Kentucky, September 5. He founded his own company in 1896 after 16 years with Standard Oil Company of Kentucky.

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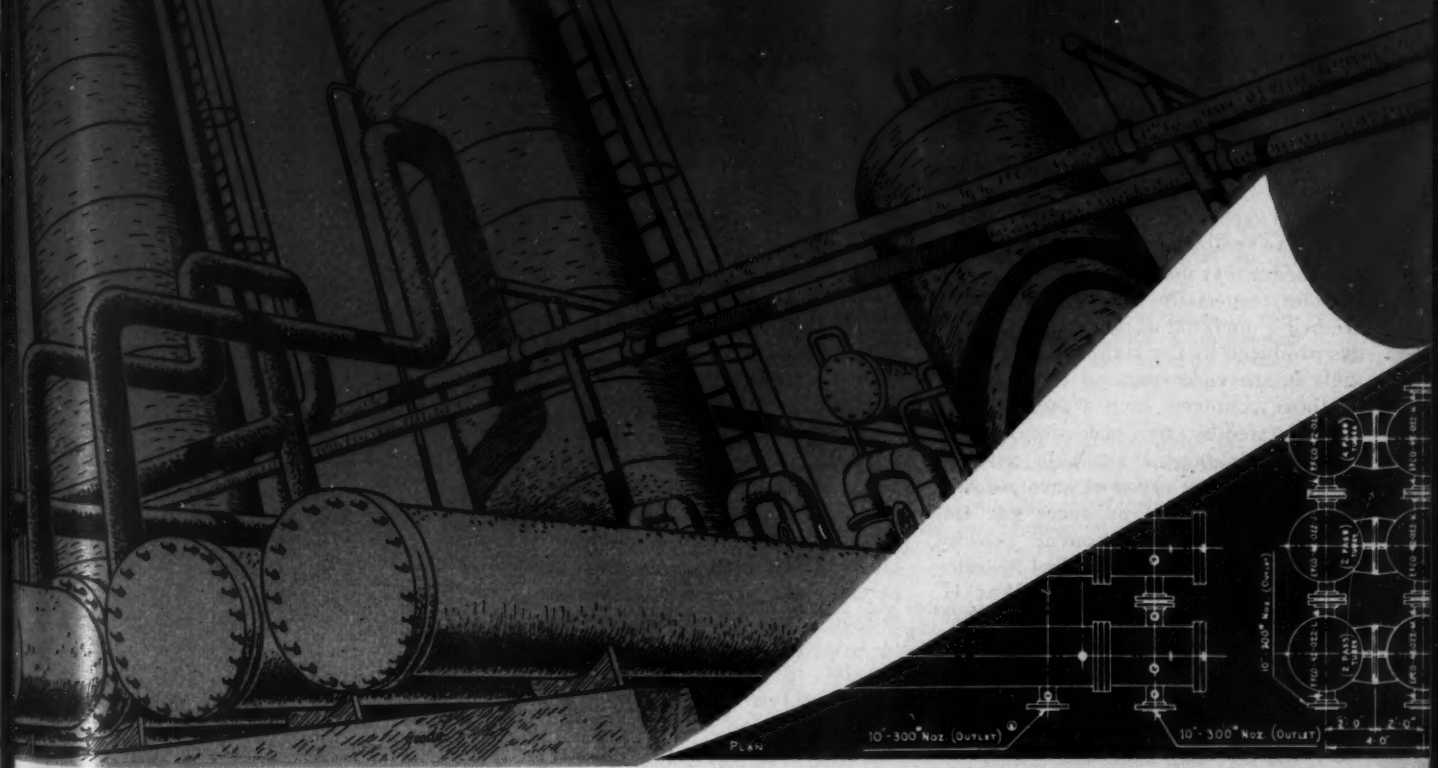

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Producer Gas As a Substitute For Motor Fuel

GUSTAV EGLOFF and PAUL TRUESDELL, Universal Oil Products Company

WOOD-BURNING stoves, long since banished from most American parlors in favor of central heating, may some day reappear in our midst as the power plants of our motor cars.

Those who fear that our reserves of crude oil are being rapidly exhausted are seriously proposing that our supplies of gasoline be supplemented, if not replaced altogether, by producer gas, generated from wood or charcoal burned in a stove built in as a part of a car, truck, or bus, or towed behind it on a trailer. This type of vehicle is known as a gasogene.

The change to producer gas would alter the entire motoring economy of the nation. Instead of oil drillers, roustabouts, and pipeliners, the American motorist would depend upon lumberjacks; instead of refinery experts, he would rely upon sawmill workers. The woodyard would replace the modern filling station. Instead of a tank holding 20 gallons or so of gasoline, the motorist would have to haul around a stove weighing from 300 pounds to more than 1000 pounds, and a bin containing about 100 pounds of firewood—equivalent to not more than 5 gallons of gasoline.

The proposal thus to revolutionize our American motoring system is predicated on the fact that more than 820,000 motor vehicles, especially busses and trucks, are being operated in many countries on gas produced by the combustion of solid fuels in stoves carried on the vehicles. In those countries such a measure has been dictated by stern necessity, because of the shrinking of available gasoline supplies or other types of gasoline substitutes. The use of producer gas and the manufacture of gasogene vehicles have, therefore, been multiplied 90 times since the beginning of World War II.

In 1938 Europe was using about 9000 gasogene vehicles, while only a few were operated on any other continent. In 1941 about 450,000 such vehicles were in operation, and the latest figures for 1942 show approximately 820,000 in 24 countries. The producer gas to drive these vehicles replaced about 25,000,000 barrels of gasoline, which the motorists would certainly have used in preference had they been able to get it.

Although a number of other solid fuels are used in other countries, wood and charcoal are the ones most often proposed for the United States. It has been estimated that 20 pounds of dry wood are needed to deliver the mileage produced from one gallon of gasoline. What would this mean in terms of trees and acres of forest land necessary to supply the mileage equivalent to that delivered by 25,000,000 barrels, or 1,050,000,000 gallons, of gasoline?

This question was put to a forestry expert, and here is his reply:

"We assume that for the purpose stated hardwoods would be preferable to softwoods. A well-stocked stand of mature hardwood timber may be expected to yield 25 to 30 cords of green wood per acre. Probably about half of this amount would be in the form of saw timber which very likely would not be available for the production of wood gas. This would leave from 12 to 15 cords of green wood per acre (weighing approximately 4000 pounds) or an equivalent in dry wood (2000 pounds per cord) of about 12 to 15 tons per acre. Thus, according to your figure of 20 pounds of dry wood per gallon of gasoline (other estimates are 24 pounds), a ton of dry wood would equal 100 gallons of gasoline or the yield per acre would be from 1200 to 1500 gallons.

"To complete the estimate on a basis of 25 million barrels of gasoline per year, the acreage of hardwood timber required would range from 800,000 to 1,000,000 acres.

"If softwood species were considered, then the yield per acre would have to be figured on a basis of about one half that of hardwood timber.

"Estimates of standing timber in the United States, of which only about 18 percent are hardwoods, indicate 282 million acres of commercial forest land of saw timber size. In addition, there are 100 to 200 million acres of commercial forest land below saw timber size."

Put in another way, if all the 820,000 gasogene vehicles now running were propelled by wood gas, it would be necessary to cut down 125,000,000 trees a year. Figuring the average tree age as 100 years, there would be an annual destruction of 12,500,000,000 years of tree life. These figures do not include any waste wood from lumbering and sawmill operations that might be used for gas production.

Consider the picture here in the United States where we have more than 32,000,000 motor vehicles on the road. In 1941, a normal year, our gasoline production amounted to more than 28,000,000,000 gallons. On the basis of data presented, it would be necessary to cut down 3,000,000,000 trees a year in order to furnish enough gas to equal the 1941 production of gasoline. This would mean the destruction of 300,000,000,000 years of tree life and the denuding of more than 23,000,000 acres of woodland. Think of the armies of lumberjacks that would be required, the vast additional sawmill capacity, and the changes in transportation! Wood blocks cannot be pumped through pipelines or hauled in tank cars or shipped in tankers. And how long would it take to reduce this country to the treeless state of China?

The gasogene is a stranger to us in this country, but in Europe four types of producers have been developed: (1) up-draught, (2) down-draught, (3) cross-draught, and (4) double-draught and double-zone. In the down-draught type of producer the flow of air and gas is in a downward direction concurrently with the fuel. This is probably the only type that would be used in the United States, as it is most suitable to burn wood and charcoal.

The gasogene includes a generator with a fuel-hopper, coolers, filters (to dedust the producer-gas stream), gas throttle, and in some cases a starting fan and water regulator.

Most of the machine is made of sheet metal. Hoppers, coolers, and filters are usually galvanized or painted to lessen corrosion. Grates and tuyeres are made of alloys to resist heat and oxidation. The generator is lined with a refractory such as carborundum, magnesite, bauxite, or fire clay.

Utilization of wood presents problems not encountered in the gasoline engine. For example, wood deposits tar and acids, so that cleaning and corrosion problems are of sizable importance in the selection of materials of construction.

On trucks the generator is commonly

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This industry requires large-scale compression of gases in connection with nearly every basic process. CLARK Compressors stand first in volume of compressor sales to the industry, with a total of approximately 75,000 horsepower, to date. They stand first because they offer the most!

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"MONTY"
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To Last for the Duration, Cars Need BIGGER RATIONS OF BETTER LUBE

The need for quality lubricants was never as great as it is today—cars now on the road *just must last*—jallopies, or sleek streamliners, they can't be replaced. And they need the best lubrication care to help stretch rationed gas and to minimize repairs.

Modern refining methods that will produce maximum capacity of high quality specification lube oils are needed to meet this urgent obligation. Filtrol engineers, with their highly activated agent, "Monty," will help you. The engineers will survey your plant, study your processing technique and make recommendations that should result in a marked increase in both the quality and the quantity of your lubricating oils. Super Filtrol will help attain these desired results too—it will produce better oil, and more of it, at lower cost, and with less equipment. Quality is the significant thing today—and we can help you attain it. Filtrol Corporation, 634 S. Spring St., Los Angeles, California. Plants: Vernon, California and Jackson, Mississippi.

Super **FILTROL**

THE ACTIVATED AGENT SPEEDS PRODUCTION–CONSERVES MATERIALS

mounted near the front, either on one of the sides or just back of the cab. On busses and pleasure cars it is in the rear and may be carried on a small two-wheel trailer. Coolers are ordinarily placed beneath the vehicle. The filter is also placed there, provided it is horizontal. A final filter, if used, is located near the intake manifold. The wood is used in the form of small blocks or chunks.

The approximate composition of producer gases derived from wood and charcoal is shown in the following table:

	Wood (Average Percent)	Charcoal (Average Percent)
Carbon monoxide	20	30
Carbon dioxide	11	2
Hydrogen	17	10
Hydrocarbons	2	0-2
Nitrogen	50	56-58

Here is the way the gasogene engine operates. First, the generator is charged with wood. When the engine is cold, it is customary to start operations with gasoline and to use it as an exhauster to draw the flame through the fuel bed from a torch inserted into the mouth of the tuyere. Ignition of the fuel takes place in about one minute, and the complete starting operations, from the time of inserting the torch to the time when the vehicle moves off on producer gas, takes from two to four minutes.

Full power is not developed for some twenty minutes after starting, during which time it may be necessary to make occasional adjustments in the air control valve. When full power is developed, the performance becomes steady, and the conrtols require little, if any, more attention than on a gasoline-driven vehicle.

Imagine an American motorist, used to an answering surge of power from his engine the minute he steps on the starter, going through this procedure!

What do they think of gasogene motoring in the countries where they know it best? One answer to that question has been given in the report of the Committee on the Emergency Conversion of Motor Vehicles to Producer Gas in Great Britain, which makes plain that the gasogene vehicle would never be widely adopted except as a measure of dire necessity. The report reads in part:

"It must, however, be remembered that, as compared with liquid fuel, producer gas suffers from various disadvantages. These include increased capital and maintenance costs, extra consequent interference with operating schedules, a reduction in pay load, and, at one time, some difficulty in obtaining really suitable fuel. Further, in some cases, the addition of producer gas equipment would have had the ef-

RATING INCREASED BEYOND PRESENT LIMITS

"Pinwheel Action"

A NEW GAS BURNER PRINCIPLE — PERMITS GREATER HEAT RELEASE PER CUBIC FOOT OF FURNACE VOLUME

Coppus-Dennis FANMIX Gas Burner utilizes the Dennis principle of combining gas with air in a perfect ratio. "Pinwheel Action" produces complete combustion without impingement — truly "radiant heat". A constant temperature exists throughout the furnace; no drifting hot-spots.

One simple change in your equipment — installation of FANMIX — will give you the extra thru-put you are undoubtedly looking for.

And here's real efficiency. With Coppus-Dennis FANMIX Burner, typical flue gas analysis shows over 11% CO_2, a fraction of 1% of O_2, no trace of CO., when burning 1000 B.T.U. natural gas.

"PINWHEEL ACTION" FOR PERFECT MIXTURE

The energy in gas under pressure does the work. Gas escaping from radially-spaced orifices in driving arms, rotates the fan; this in turn causes intake of air at right angles to the path of the gas. Gas and air are thus mechanically mixed in correct proportions for complete combustion.

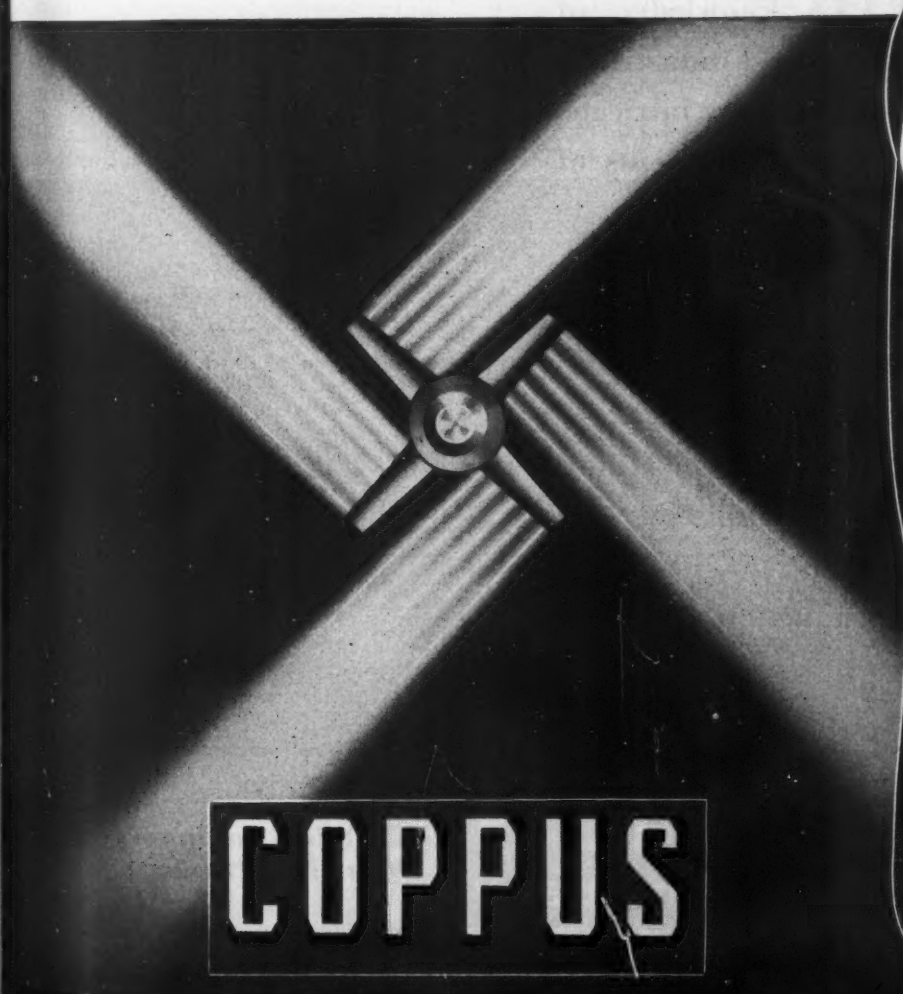
GREATER HEAT RELEASE PLUS!

Bulletin 410-3 describes other FANMIX advantages: — smaller combustion space, less stack, no forced draft equipment needed, no cracking of wet gas, because driver arms stay below "cracking" temperature. A Coppus "Blue Ribbon" product — precision-engineered, precision-built.

COPPUS ENGINEERING CORPORATION

420 Park Avenue, Worcester, Mass.

Sales Offices in THOMAS' REGISTER. Other "Blue Ribbon" Products in REFINERY CATALOG

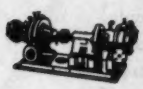


COPPUS

You'll get valuable ideas from these free bulletins on other Coppus Blue Ribbon Products

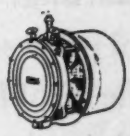
(Check the ones you want)

☐ Coppus Cable Manhole and Tank Ventilators. For confined working spaces. Bulletin 163-1.

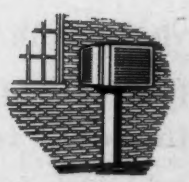


☐ Coppus Steam Turbines. 6 sizes (and prices) from 150 H.P. down to fractional. Bulletin 135-9.

☐ Coppus Heat Killers. Keep production up by keeping men cool. No stale air recirculation. Air is directed. Bulletin 160-5.



☐ Coppus Type C Turbo Blower. For undergrate draft. Bulletin 145-6.



☐ Coppus Air Filters. For engines and air compressors. Perfect, uninterrupted filtration. Bulletin F-310-4.

☐ Coppus-Dennis Fanmix Gas Burner (described in this ad).

Name.....

Company.....

Address.....

City..... State.....

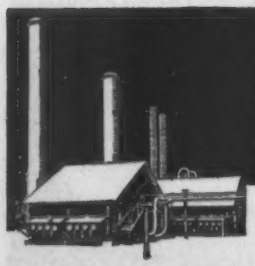
COPPUS BLUE RIBBON PRODUCTS DESIGNED FOR YOUR INDUSTRY . . . ENGINEERED FOR YOU

"The life and soul of science is its practical application."
—Lord Kelvin

1820-1872
William John MacQuorn Rankine was the pioneer of the modern science of thermodynamics on the bases established by Carnot and Joule. He was the author of the first formal treatise on the subject.

Rankine also developed a practical formula for the calculation of the efficient utilization of the latent heat of vaporization. Rankine was also an engineer and understood the practical application of his physical research.

Scientific knowledge of heat has had some of its most industrially useful applications to the many intricate, exacting, everchanging requirements of oil processing. Pioneering 19 years ago in the problems of heating hydrocarbons, Alcorn has devoted its engineering ability to the solution of the heating problems vital to the processing of every type of petroleum product. Alcorn installations in world important refineries have achieved new standards for high efficiency for peak production, for low operating costs.



ALCORN
Combustion Company

SCHAFF BUILDING, PHILADELPHIA
Los Angeles • Houston • San Francisco

fect of placing good vehicles in a higher tax category and perhaps also in a lower speed-limit category.

"The net result has been that, in peacetime, producer gas, at the present stage of development of producer design, is of doubtful economic value for motor vehicles, except in specially favorable circumstances, e.g., for long distance work with vehicles carrying medium or heavy loads.

"Even in France, where producers have reached an advanced state of development, where charcoal, which is an excellent fuel, is available in large quantities for use in them, and where petrol is dearer than in England, there were in 1938 only about 4,000 producer gas vehicles, which is only a small proportion of their total transport.

"It should be mentioned, too, that producers in France received a large measure of government encouragement, e.g., almost complete remission of taxation."

The following table shows the distribution of gasogenes in use in various nations in 1942:

	Maximum Number of Vehicles Reported in Use
Axis-Controlled Countries	
Germany	350,000
France	110,000
Italy	35,000
Denmark	20,000
Belgium	15,000
Hungary	6,000
Norway	3,500
Holland	1,000
Slovakia	50
Total	540,550
Neutral Countries	
Sweden	72,755
Switzerland	15,000
Spain	2,200
Ireland	1,100
Portugal	450
Total	91,505
Allied Countries	
Russia	100,000
Australia	45,000
Brazil	22,000
India	10,000
Britain	10,000
Chile	1,000
China	500
South Africa	100
Scotland	47
United States	6
Canada	1
Total	188,654

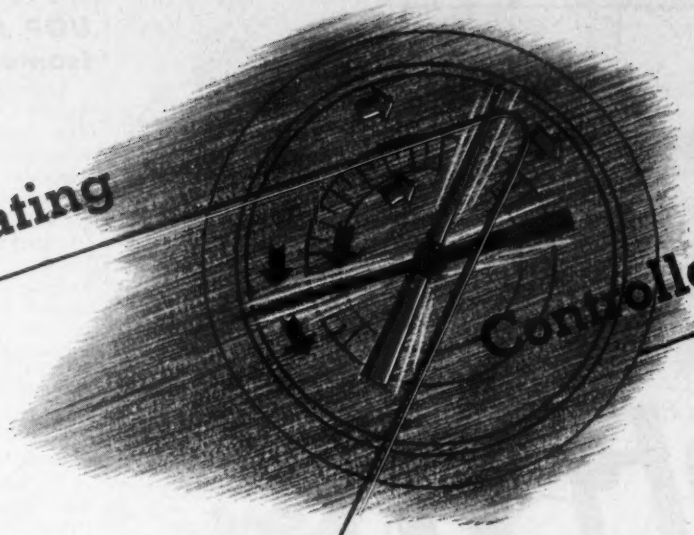
In the United States of America there are just six gasogene vehicles. In view of our oil resources, it is unlikely that producer gas will play an important role as motor fuel in our economic life.

Chemical Engineers to Meet in Pittsburgh

The annual meeting of the American Institute of Chemical Engineers will be held November 15 and 16 in Pittsburgh. Headquarters will be at the William Penn hotel.

This will be the thirty-sixth meeting of the organization.

Accurate Heating



Controlled Cooling

—with one heat transfer medium!

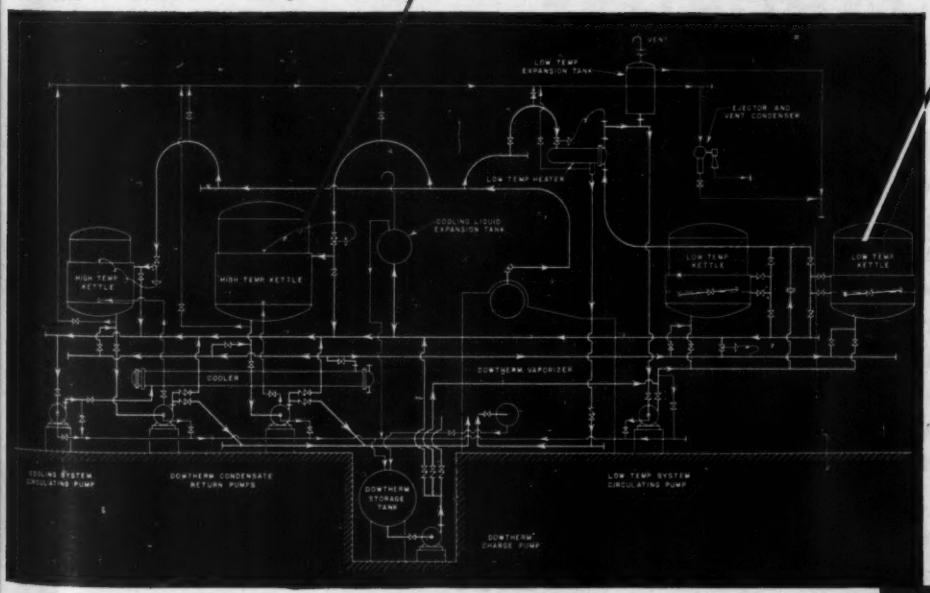
A synthetic resin plant now producing for Victory provides an excellent example of how Dowtherm can be made to serve a double purpose. Not only is close control available at high temperatures with Dowtherm vapor, but controlled rapid cooling can be effected by circulating liquid Dowtherm through the same system after the heating cycle is completed.

Because Dowtherm assures accurate, closely controlled temperatures, a greater uniformity and better quality of the product results. By designing this resin plant specifically for Dowtherm, it was possible to simplify it greatly. The result was a substantial economy in materials and manpower.

This installation is only one of many designed to take advantage of the flexibility of Dowtherm—the high temperature, low pressure heat transfer medium. Perhaps Dowtherm can aid you in improving your product with a saving in men, money and materials.

THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

New York • Cleveland • Chicago • St. Louis • Houston • San Francisco • Los Angeles • Seattle



FLOW DIAGRAM OF THE RESIN PROCESSING EQUIPMENT

Arrangement of high temperature and low temperature reactors for resin processing. Provision is made for rapid cooling of all reactors with Dowtherm liquid. Heat for processing is derived from the Dowtherm vaporizer, Dowtherm vapors being used for the high temperature section and liquid Dowtherm being used for the low temperature section.

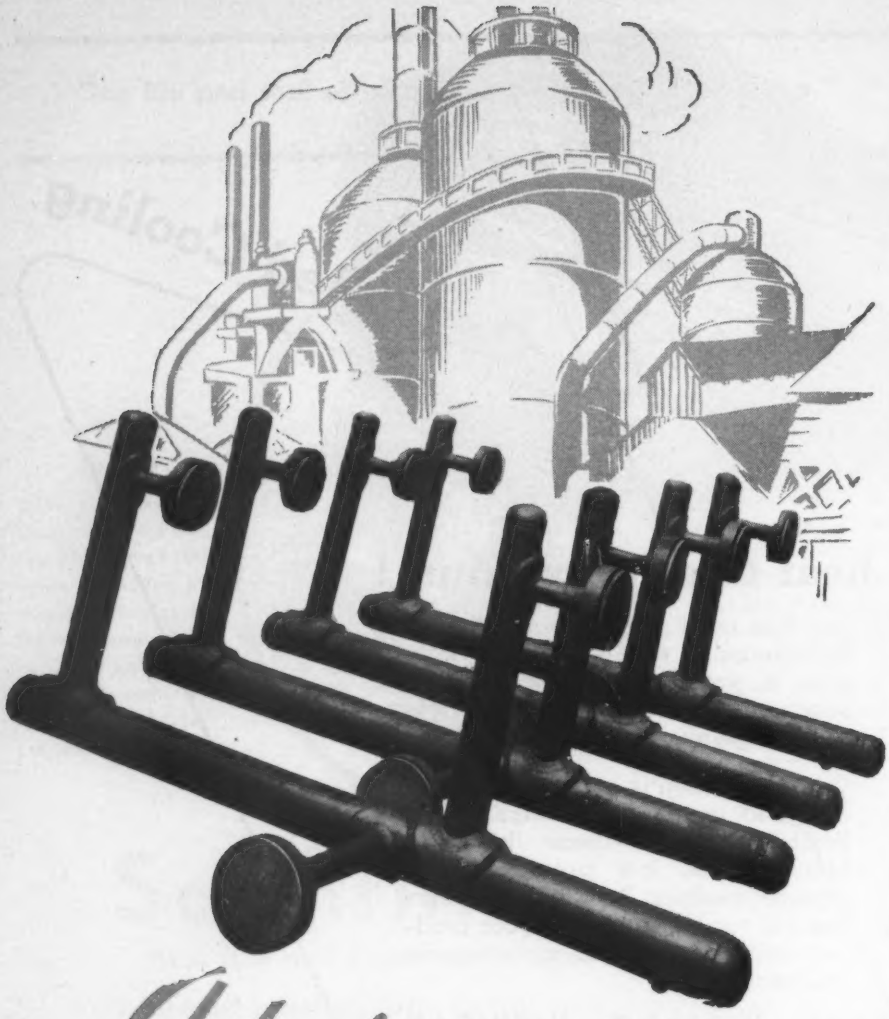
FLOW SHEET COURTESY OF FOSTER-WHEELER CORP.

DOWTHERM

THE HIGH TEMPERATURE, LOW PRESSURE, HEAT TRANSFER MEDIUM

DOW

CHEMICALS INDISPENSABLE TO INDUSTRY AND VICTORY



Arteries OF STEEL

FASHIONED FOR INDUSTRY

The vital needs of war industries for fabricated piping in all its multi-phases are being fulfilled constantly in Associated shops. Time is usually a basic factor. On this premise, Associated services become increasingly comprehensive. For example, high pressure, high temperature alloy fabrications are completed without looking to secondary sources for flange requirements. This is possible because Associated manufactures flanges (2500 lb. carbon moly ring joint flanges on fabrications pictured above). Time saved by this unusual auxiliary service alone is worth — how much?

Whatever your power fabrication requirements, let Associated do the work

WAR PRODUCTION . . . This company is engaged in high priority war production, proud of its responsibilities and fulfilling them to the letter.

ASSOCIATED PIPING & ENGINEERING CO., INC.
2332 EAST 38TH STREET
LOS ANGELES, CALIFORNIA

UOP Announces Pentane Isomerization Process

Universal Oil Products Company, 310 South Michigan Boulevard, Chicago, has developed a catalytic process for isomerization of pentane. It is now available to the refining industry. Part of the announcement gave these details:

"The process is simple, continuous in operation and easily controlled. It produces high yields at relatively low recycle rates, and dispenses with the use of hydrogen. Catalyst consumption is low.

"Isopentane is a necessary component of 100-octane-aviation gasoline. It is the best hydrocarbon available to give aviation gasoline the required vapor pressure of seven pounds; improve the octane rating; increase the volume.

"Isopentane, in addition to being valuable in aviation fuel, will play a prominent part in the production of high-quality postwar motor fuels.

"Considerable amounts of isopentane are contained in the base stock produced by catalytic cracking. It is necessary, however, to supplement this supply from other sources. One of these, natural gasoline, contains large quantities of normal pentane but a limited amount of isopentane."

New Type of Black to Be Made by Phillips

Construction of a furnace black plant for the manufacture of a new type black has been announced by Phillips Petroleum Company of Bartlesville, Oklahoma. The new plant, which will produce approximately 22 million pounds of the new type black per year, is being built as a private enterprise by Phillips adjacent to the Phillips designed and operated government butadiene manufacturing plant in the Texas Panhandle. Full scale production is anticipated before the close of the year.

Thirty to 40 pounds of black are required in the compounding of each 100 pounds of synthetic tire rubber, and this new type furnace black called "Philblack" is the result of years of intensive research by Phillips to develop a black particularly adapted to the manufacture of synthetic rubber automobile tires.

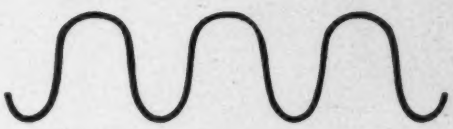
Association to Provide Lubricating Test Engines

Engines for determining the service behavior of lubricating oils will be added to the laboratory of Pennsylvania State College by the Pennsylvania Grade Crude Oil Association. In making public this recommendation of its technical advisory committee, the association explained:

"The laboratory has carried on the so-called 'bench tests' on lubricating oils for many years and will now be able to supplement information thus obtained by actual engine runs. Correlation of the results of each type of test will give the petroleum chemist further insight into the character and quality of the material and enable him to predict the ultimate performance of lubricants in actual motor-vehicle operation with a greater degree of accuracy. Additional information obtained through these combined approaches to the problem will then be available to the manu-

"Your life-line

is perfectly formed . . . UNIFORM—no thick-and-thin sections . . . *ALL-CURVE*—no weak corners or 'junctions.' I see a long life ahead for you."



SINCE 1841 we've learned a lot about working sheet metals and tubing into all manner of shapes *without dangerous forming stresses.*

In putting those deep corrugations into Badger Corrugated Expansion Joints, no "shock" methods are used . . . no hammering, forging or sharp die-pressing to stretch or weaken the metal.

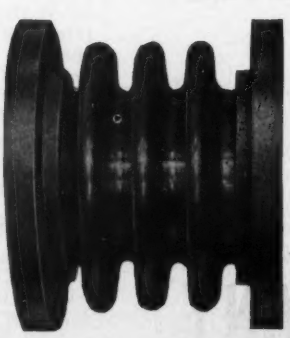
Badger joints are "babied" into shape—a step at a time—by special Badger-perfected means and under scientific heat-treatment during fabrication.

Result: Into your pipe line goes a joint that is uniformly resistant to temperatures and pressures, and as responsive to expansions and contractions as modern engineering can make it. . . . A joint with *ALL-CURVE* corrugations—no straight sides or "junctions" to encourage localized stresses. . . . A joint that will retain its flexing characteristics under long and severe use.

• • •

FREE BADGER BULLETINS (see left) tell more about the *ALL-CURVE* Corrugations, *ALL-CURVE* Equalizing Rings, Directed Flexing, "Packless" and other features of Badger Corrugated Expansion Joints.

BADGER DIRECTED FLEXING SELF-EQUALIZING EXPANSION JOINTS—*ALL-CURVE* Equalizing Rings not only control and limit the flexing movement, but reinforce the joint to far beyond the "safety" point. For long traverses. Made of Stainless Steel for higher pressures and temperatures and corrosion resistance. Also made in Copper for steam distribution. *Bulletin No. 100.*



BADGER NON-EQUALIZING (packless) EXPANSION JOINTS —with single or multiple corrugations for lines where pressures do not exceed 25 pounds and traverses not exceeding ½". Also used to absorb strains, vibrations and distortions between connecting equipment. *Bulletin No. 200.*

IF IT'S **BADGER**-MADE IT'S **GOT SOMETHING!**

E. B. Badger & SONS CO.

75 PITTS STREET, BOSTON, MASS.

AGENTS IN PRINCIPAL CITIES

BADGER CORRUGATED EXPANSION JOINTS

Air-conditioning ducts in the attic of a large theatre. The Koldboard was applied directly to the duct surface and held in place by 16 gauge wire. All joints sealed with hot asphalt.

Condensation difficulties which occur in low temperature ducts can be eliminated by the use of B-H Koldboard. Made from B-H *Black* Rock-Wool, Koldboard is moisture repellent, chemically stable, and non-combustible—the perfect combination for maximum insulating efficiency. The fibres are felted and bonded together to form flat, semi-rigid blocks.

Effective for temperature ranges from −150° to 300° F it provides ideal low temperature insulation for cold storage rooms, air-conditioning ducts, refrigerators, roof insulation, marine bulk heads, ship hulls, etc. Tests by well-known testing laboratory show that B-H Koldboard has a thermal conductivity of 0.32 BTU/sq. ft./hr./° F at a mean temperature of 75° F.

Send for a generous size sample of B-H Koldboard and copy of current catalog.

BALDWIN-HILL INSULATIONS

BALDWIN-HILL COMPANY

567 KLAGG AVE. • TRENTON 2, N. J.

NEW YORK, N. Y. • CHICAGO, ILL. • KALAMAZOO, MICH. • HUNTINGTON, IND.

facturers of Pennsylvania grade lubricating oil.

"The latest step is a part of the broader program of development in research voted by the board of directors recently. Other studies which will be inaugurated soon, include investigation of production methods, designed to increase the output of crude oil from the region. The problem of providing more and more Pennsylvania grade petroleum for the nation's war program is a serious one and oil men in the region are bending all their efforts in that direction."

The Texas Company Opens New Plant in Chicago

Large quantities of toluene are now being manufactured in a new $6,800,000 unit at one of The Texas Company's refineries in the Chicago area.

The new unit, first to be constructed in Illinois, was built under an Army Ordnance contract.

No formal opening ceremonies were held at the plant, as it was felt that the time could be spent more advantageously in actual production.

Cook Will Do Special Assignment for PAW

Kenneth E. Cook, of the public relations department of the Standard Oil Company (New Jersey), 30 Rockefeller Plaza, New York City, has been granted a leave of absence to join the public relations department of the Petroleum Administrator for War in Washington. Cook will be engaged on a special assignment which is expected to be completed within three months.

Argyle Assistant PAW Refining Director

William R. Argyle has been appointed assistant director of the refining division of the Petroleum Administrator for War. He is on leave from Sinclair Refining Company, being assistant manager at the Marcus Hook plant.

After graduation from the University of Utah in 1915 he joined the staff of the United States Bureau of Mines. Five years later he became a fuel engineer with Sinclair Refining Company. He was superintendent of the Marcus Hook plant from 1920 until his recent promotion to assistant manager.

Warren Transfers Thompson To Oklahoma Gasoline Plant

P. E. Thompson, who has been superintendent of the natural gasoline plant of Warren Petroleum Corporation, Salem, Illinois, has been transferred to the new plant in the Madill field, Oklahoma.

C. V. Quinn, who has been at the Madill plant, will become superintendent at Salem.

Morgan Is a Director of Standard of Louisiana

Judge Cecil Morgan, general attorney of Standard Oil Company of Louisiana, Baton Rouge, has been elected a vice president and director. He succeeded Judge Thomas M. Milling, general attorney, who retired August 1.

Judge Morgan has been affiliated with Standard Oil Company of Louisiana since November 1, 1936, when he re-

Simplifies Purchasing and Layouts

By specifying a factory-assembled group for your high-voltage control, you consolidate the selecting, ordering, and laying out of individual devices into one simplified process—saving hours for your engineers, purchasing men, and draftsmen.

Saves Installation Time and Space

Instead of separate devices, you install only one control board. The individual starters, each combining an oil-immersed contactor and EJ-2 fuses in a single metal cubicle, are pre-assembled into a compact group, which is wired and shipped as a complete panel. Just set it in place and connect the incoming line and outgoing motor leads.

Conserves Critical Material

Because of the compact arrangement of these starters into a group, you save the vital material that would be used for bus, conduit fittings, and wire connections on separately installed controls.

For further information, get in touch with the nearest G-E office. One of our sales engineers will be glad to help you select 2300-volt control for your plant. *General Electric, Schenectady, N. Y.*

676-91-8920

GROUP CONTROL FOR CORROSIVE OR SEMIHAZARDOUS LOCATIONS

For full-voltage or reduced-voltage starting of induction or synchronous motors which drive pumps, blowers, compressors, and other equipments, indoors or outdoors. Individual starters can be supplied for isolated locations.

GENERAL ELECTRIC

CONTROL

Make Good Piping Better

with

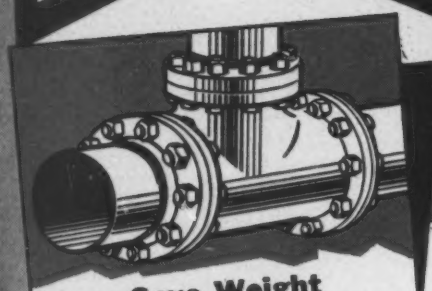
WELDOLETS • THREDOLETS

3 Types Meet Every Need

WeldOlets for butt welded branch connections.

ThredOlets for screwed branch connections.

Socket-End WeldOlets for socket-type welded branch connections.

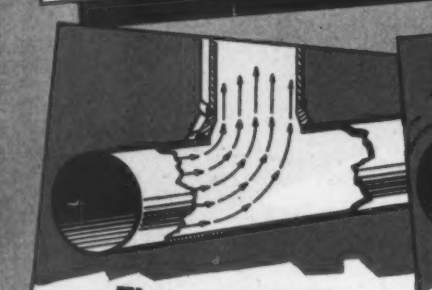


Save Weight

WeldOlets, ThredOlets keep the weight of any piping system to a minimum. Fewer flanged joints mean less possibility of leaks.

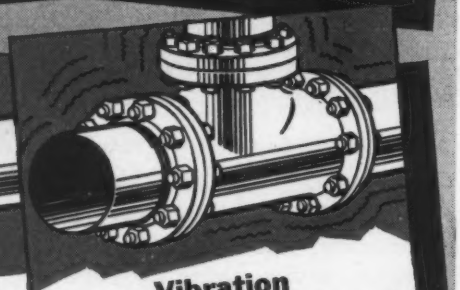
Gaskets, Bolts, Nuts

Maintenance eliminated when WeldOlets, ThredOlets are used—no need to change gaskets, tighten nuts and bolts.



Flow Improved

Funnel-shaped intake aperture of WeldOlets, ThredOlets improve flow conditions, reduces turbulence and friction.



Vibration

Due to light weight and improved flow conditions, vibrational stresses are reduced, possibility of leaks eliminated when WeldOlets, ThredOlets are used.

WeldOlets, ThredOlets and Socket-End WeldOlets are suitable for all commonly used pressures and temperatures in every type of piping system. They are installed either before or after erection of the main line—and always with ease and economy. They are equally well adapted to pre-fabricated or "on-the-job" assemblies. Stocked for all standard pipe sizes up to 12" in size-to-size and reducing sizes—and can be supplied on special order for pipe up to 24". Stock fittings are drop forged steel, but to meet special conditions will be supplied in Monel, Everdur, Toncan Iron, wrought iron, etc.

Bulletin WT31 gives detailed information about all the advantages of WeldOlets, ThredOlets and Socket-End WeldOlets. Write for your copy today.

Forged Fittings Division

Bonney Forge & Tool Works, Allentown, Pa.

ARMY E NAVY

Star Awarded July 10, 1943

WELDOLETS•

TRADE MARKS REG U.S. PAT. OFF.

THREDOLETS

Welded Outlets for Every Piping System

signed as Judge of the First Judicial District Court, Caddo Parish, to which he was first elected May 2, 1934, to become attorney for the company in Shreveport. He moved from Shreveport to Baton Rouge in September, 1941. He is a graduate of Louisiana State University.

From 1928 to 1932 he was a member of the Louisiana House of Representatives from Caddo Parish and in 1932 he was elected a member of the State Senate from the 25th Senatorial District of Louisiana, from which post he resigned when elected to the Caddo District bench.

Frontier Is Completing Aviation Gasoline Units

Frontier Refining Company, Cheyenne, Wyoming, is completing units which will provide substantial output of aviation gasoline. The plant had capacity of 1600 barrels daily and cracking capacity of 750 barrels when plans were made for adding units for processing to high-octane gasoline.

Processes added by Universal Oil Products Company include fluid-flow-catalytic cracking, hydrogen-sulfide alkylation, butane isomerization, thermal reforming and a gas concentration unit of UOP design.

Safety With Glass Tubes

"How many of your laboratory workers have been injured in the past year while handling glass tubing? It would be wise to make a study of this problem for it harbors real danger.

"A survey was made recently of four laboratories in a large oil refinery, and to the surprise of all concerned, the glass tube cuts and puncture wounds were found to be not only the most frequent type of injury, but also the most severe. Four workers were found to have incurred permanent partial disabilities in recent years due to glass tube cut accidents. One had a stiff finger, another lost some use of a hand, and another had injured tendons in a wrist. But the case that attracted most interest and sympathy was the result of a glass tube cut barely ⅜-inch long at the base of a little finger near the hand. This man has undergone five operations in the past 7 months, and a total of 16 hours on the operating table—and was on his way to a distant city to a plastic surgeon for his sixth operation when he was interviewed.

"Which brings us to the the point of what can and should be done to prevent these injuries. Here's a partial list of safe practices developed by the personnel in the laboratories surveyed looking to the prevention of such accidents:

"1. The ends of all glass tubes must be fire polished.

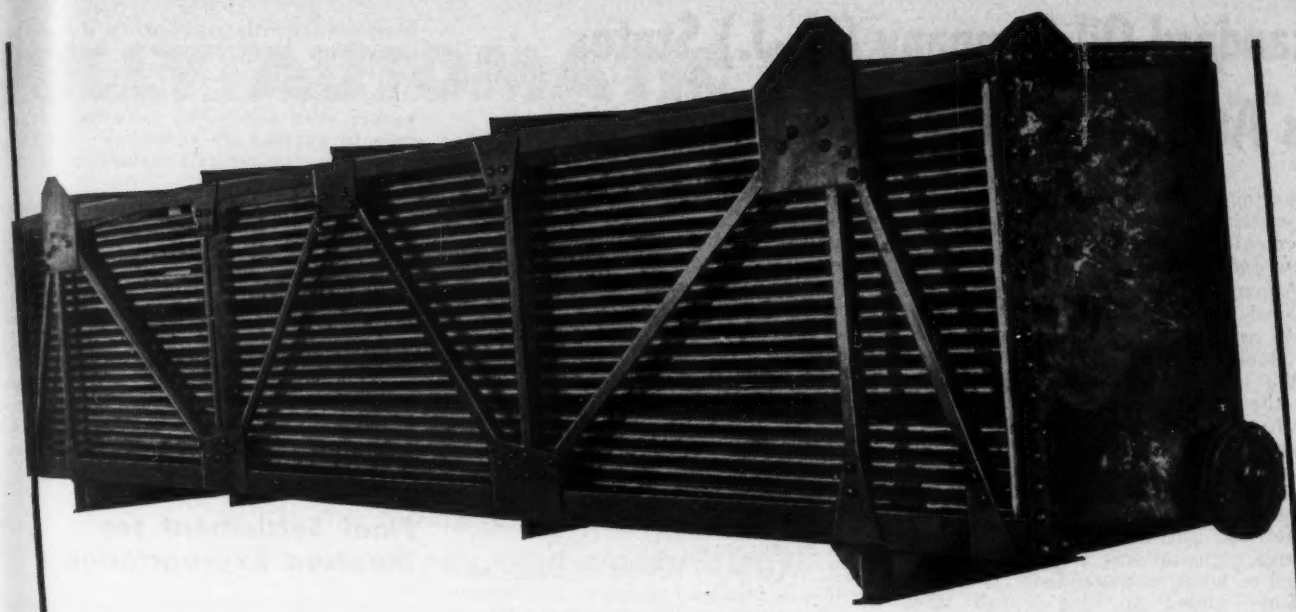
"2. A glove or cloth protector must be used when inserting glass tubing into rubber tubing or stoppers or corks.

"3. The tube end should be moistened with glycerine or some other suitable liquid.

"4. Grasp the tube close to the end where pressure is applied, and work it into the rubber tubing or stopper or cork with a slow rotating motion.

"5. Discard all glass tubing with visible defects."

—Petroleum Safety



Sour Naphtha ON THE INSIDE

Polluted River Water ON THE OUTSIDE

ANACONDA ADMIRALTY CONDENSER TUBES BETWEEN...

Those are the conditions under which this bank of three-pass, self-draining submerged condensers operate on rerun stills for a Southern oil refinery. Designed and fabricated by J. B. Beaird Company, of Shreveport, Louisiana, Anaconda Admiralty Condenser Tubes were selected as the most desirable for this particular requirement.

But in oil refineries, operating conditions for condensers and heat exchangers are seldom the same. Liquids and vapors have various degrees of corrosiveness. Working temperatures are frequently high. Corrosive chemicals are commonly added to neutralize objectionable elements. Water supply is often inadequate, making necessary the use of cooling towers with the inevitable accompaniment of harmful air saturation.

Because of the complex conditions under which condensers and heat exchanger tubes must serve, The American Brass Company manufactures a wide range of tube alloys. In addition, Engineers of our Technical Department, having devoted years to the study of these conditions in various combinations, are prepared to help users select the most economical alloy. 4399

ANACONDA

Anaconda Condenser Tubes

THE AMERICAN BRASS COMPANY • General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company • In Canada: Anaconda American Brass Ltd., *New Toronto, Ont.*

BUY ALL THE BONDS YOU CAN AFFORD . . . TURN IN ALL THE SCRAP YOU CAN FIND

Standard Oil Company (N. J.) States Its Attitude in Regard to Cartels

Continued discussion of the propriety of cartels resulted in the following statement from Standard Oil Company (New Jersey):

"Apparently, 'cartels' are to become a political issue.

"As one American corporation which has done business all over the world to the benefit of American consumers and the nation as a whole, we should like to state our position.

"At one time, a generally accepted definition of the word 'cartel' was 'a combination to control production and fix prices.' But over the past few months 'cartel' has gathered to itself new and strange connotations. It has been subjected to what propagandists call 'name calling — giving an idea a bad label which is used to make us reject and condemn the idea without examining the evidence.' The word 'cartel' has become the label of something 'bad.' As an emotional symbol, it calls forth the response of a 'secret,' 'un-American,' 'contract with foreigners.'

"Clearly, then, our views on agreements which control production and fix prices are not enough. We must also say what we think about some other things —including 'secret' agreements and 'contracts with foreigners.' Here are our views:

"1. We do not believe in controlling production—whether it is done by bureaucratic expedient or by business men behind the locked doors of board rooms. When there seems to be over-production, it is the American way to use science in finding new uses for the product, to improve the methods of distribution so that people can share what is being produced at a lower cost.

"As Justice Brandeis once said, 'The one final way in which we can improve the condition of the worker is to produce more, in order that there may be more to divide.'

"Like most responsible American corporations, we are dedicated to that American way.

"We think there is one notable exception to this general rule. Sometimes over-production threatens to waste or use up a natural resource. Then, we think it is the responsibility of government—the agent of all the people to step in and stop dangerous depletion of these irreplaceable resources. The American people have already accepted the validity of this principle. The oil-producing states, with the approval of Congress, have established the Inter-State Oil Compact for the purpose of conserving nation's oil resources. Under this compact, the governing authorities of Texas, for example, fix—in open public hearings—quotas for the production of oil within the state.

"2. We do not believe in combinations to control price. Quite aside from any moral principle involved, we think it is folly for a business to believe that it can be secure in such an arrangement. Such a business has become defensive in policy. Sooner or later somebody is going to develop better ways to make the product more cheaply and then take the market away from the price-fixers. Like most responsible American corporations, our constant objective is to be that 'somebody.' It has been our experience that a clique which has run into the dead-end street of trying to save its business by maintaining unnatural prices is the easiest kind of competition.

"Of course, there are times when government in a national emergency has to step in and control prices. We are in such a period now, when disastrous inflation would result from sharp rise in commodity prices. But even in such an emergency, price control must be handled with candor, efficiency and singleness of purpose.

"3. We are for business dealings with people in foreign countries. The American has traditionally roamed the face of the earth—bringing back new things to make life better and happier for our citizens, and carrying the gospel of the American standard of living to people in other lands. The bitter experience of two bloody and costly wars has shown that international trade must be increased, planned more intelligently, made easier—not frustrated or blocked. For one thing, everybody seems to agree that basic raw materials must be more easily, more equitably available to the people of all nations.

"The responsibility for such planning seems to us to lie with representatives of our government working together with the representatives of the governments of other nations. If that is a 'cartel,' then we are for that kind of cartel.

"Of course, when American business men do business in other countries, they must do business the way that country does it. They must obey the laws of the land. No matter how much he may prefer the way we do business in this country, no American business man can hope to change the political structure of a foreign country just to suit his convenience. For example, our government in 1922 urged American companies to secure rights to produce oil in the Near East. We attempted to acquire interests in Iraq. After six years of arduous negotiation, we entered into an agreement which limited to a certain percentage our share of the oil to be produced and restricted our producing activities throughout the whole area.

"In the United States a contract would probably violate the Sherman Anti-Trust Act. The point is, that if America was to get any of the oil of Iraq, American companies had to abide by the conditions imposed by international competition.

"4. We are against secret agreements. We think that secret agreements are a bad business policy—and that in our American democracy there is a fundamental reason for this position. In this country we are dedicated to the principle that the will of the people shall prevail. If this principle is to be effective, it means that the people must have the facts on which to form their opinions.

"It has been our observation that the judgment of the American public has been consistently right when it has the facts. Any business which deliberately follows a policy of secrecy and mystery is vulnerable to the attacks of any ill-wisher who sees some personal advantage in stirring up prejudice based on misrepresentation and distortion of the truth.

"Of course, there are times when publication of the facts is against the national interest. But here, again, responsibility for this decision should rest with government.

"We are ready to file with the Department of State—or some other designated government agency—copies of all contracts that we make with foreign corporations. If that agency considers publication of the facts to be in the public interest, we are for publishing them to the world."

Final Settlement for Mexican Expropriation

The State Department closed the controversy between the oil industry in the United States and the government of Mexico by accepting total settlement of $29,137,700.84 for properties taken over in the expropriation of March, 1938. The agreement calls for additional payments of $20,137,700.84, $9,0000,000 having been paid in 1941.

The department announced that the agreement was reached through an exchange of notes between Adolf Berle, Jr., Acting Secretary of State, and Rafael de la Colina, Mexican charge d'Affairs.

Payments under the agreement began September 30 with a remittance of $3,796,391.04, and the balance will be paid in four annual installments of $4,085,327.45 each.

The total of $29,137,700.84 which thus will represent the payment made by Mexico for properties which the companies contended were worth between $400,000,000 and $500,000,000, represents $23,595,991 plus $5,141,709.84 interest at 3 percent on all unpaid balances from March 18, 1938, to September 3, 1947, the date set for the final payment.

The first payment of $9,000,000 was made on November 19, 1941, when the two governments agreed to appoint experts to determine the just compensation to be paid for the properties. The experts, Morris L. Cooke for the United States and Manuel J. Zevada for Mexico, placed a valuation of $23,995,991 on the losses sustained by American nationals and provided at interest at 3 percent per annum from the date of the expropriation to the date of final settlement on all balances due.

In conformity with the basic agreement the evaluation was final and its terms are carried out by the arrangements announced by the department.

Petroleum Library Available To South Americans

A library specializing in petroleum techniques is now being formed at the headquarters of the Institute Sudamericano del Petroleo, Avenida Agracia 1464, Piso 90, Montevideo, Uruguay. This library will be the first one in its class in South America and will have a service of bibliographical information at the disposal of all the South American countries.

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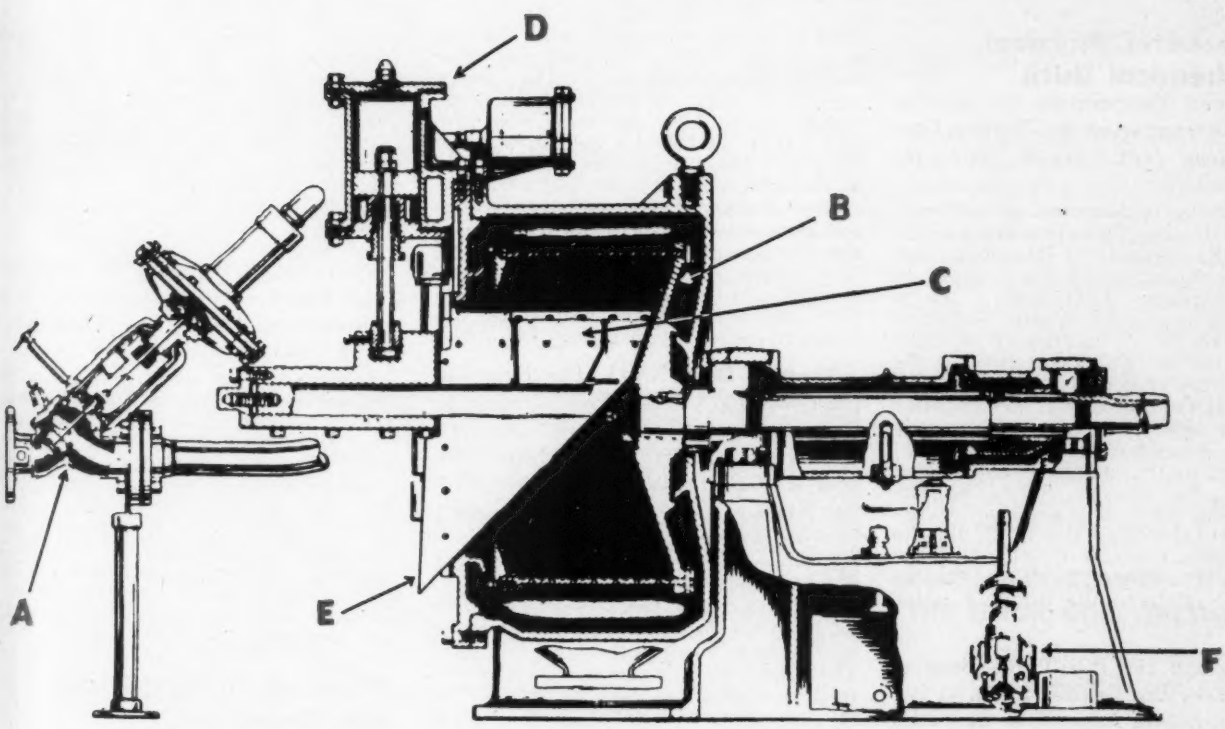

Slurry enters through the automatic valve A and feeds into the basket B, which remains at full speed through the run. Another automatic valve controls the rinse spray. When the drying cycle is completed the knife C is raised by the hydraulic piston at D and diverts the cake down the chute E. The pump F creates the hydraulic pressure. All operations are fully automatic.

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SCIENCE AND TECHNOLOGY

Abstracts prepared in co-operation with the

PETROLEUM REFINER

by

THE LESLIE LABORATORIES
Traver Road, Ann Arbor, Mich.

under the supervision of
DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical And Chemical Data

Standard Temperature for Specific Gravity Determination and Volume Correction, *Jour. Inst. Petr.* **29** (1943) pp. 190-1.

The note on temperature correction is published in the Journal to express the view of the Institute of Petroleum that 60° F. is the standard temperature to which the volume of petroleum products should be corrected when necessary, rather than 20° C. as adopted in some other industries. The Institute is of the view that the Imperial gallon should be retained as the unit of volume in British territories, and that it should remain in line with American practice by specifying 60° F. as the standard temperature to which oil volumes should be corrected. The committee proposes to reconstruct Table 4 of the U. S. Bureau of Standards Circular C. 410, National Standard Petroleum Tables, replacing the U. S. gallon by the Imperial gallon as the unit of volume.

Nomograph for P-V-T Relations of Gases Below the Critical Point, G. W. THOMSON, *Ind. & Eng. Chem.* **35** (1943) p. 895.

A correlation of the available data for hydrocarbons on the compressibility of vapors below the critical point was made by Cope, Lewis, and Weber. Their results were expressed by the equation: $u \log u = P_r f_{10}$, in which $u = PV/RT$, P_r = reduced pressure, and f_{10} = a function of reduced temperature only. A direct solution for u is not possible because of the transcendental nature of the function, but a nomograph can be simply constructed that obviates the tedious interpolation between curves necessary in a graphical solution. Such a nomograph is presented by the author.

Volumetric Behavior of Methane, R. H. OLDS, H. H. REAMER, B. H. SAGE, AND W. N. LACEY, *Ind. & Eng. Chem.* **35** (1943) pp. 922-4.

The volumetric behavior of methane was investigated at pressures up to 10,000 pounds per square inch in the temperature interval between 100° and 460° F. The equipment and methods used have been previously described. The volume of the working chamber was large enough so that adsorption did not play a significant part in the uncertainty of measurement. The gas used was prepared from gas from a field in the San Joaquin Valley. It consists essentially of methane with water vapor and a trace of carbon dioxide. The quantity of ethane and heavier hydrocarbons in the purified gas was less than 0.0002 mole fractions. The results of the experimental work are presented in tabular and graphical form, and are compared with values obtained in earlier investigations by others.

Thermal Data. XVII. The Heat Capacity, Entropy, and Free Energy of Formation of Cyclohexane. A New Method of Heat Transfer in Low Temperature Calorimetry, R. A. RUEHRWEIN AND HUGH M. HUFFMAN, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1620-25.

The heat capacity of cyclohexane was measured over the temperature range 13 to 300° K. Two measurements were made of the heat of transition and two of the heat of fusion of cyclohexane. The apparatus used in the work is described in detail, as well as the method of operation. The data taken are reported in tabular and graphical form. The molal entropy and free energy of liquid cyclohexane at 298-16° K. were calculated, $S = 48.84$ cal./degree, $\Delta F^o_f = 5.99$ kcal. The results of the authors' measurements of the heat capacity differ from those of Aston, Szasz and Fink by an amount greater than the experimental errors claimed by either.

Heats of Vaporization from Reference Substance Plot, D. H. GORDON, *Ind. & Eng. Chem.* **35** (1943) pp. 851-3.

A plot of the vapor pressure of a substance against the vapor pressure of a reference substance at the same values of reduced temperature gives a straight line the slope of which is qreal to $(T'_c/T_c) \times (L/L')$ where T_c and L represent the critical temperature and the molal latent heat of vaporization, respectively, and the primes indicate a reference substance. This is true because of the relative constancy of the ratio L/L' when both are taken at the same value of reduced temperature. From the slope of the line, from the critical temperatures of the substance in question and of the reference, the latent heat of vaporization of the substance in question can be calculated at any temperature. Other methods for calculating latent heats are briefly reviewed and discussed. Data are presented for ammonia, carbon dioxide, propane, methyl chloride, dichlorofluoromethane, dichlorodifluoromethane.

Viscosity of Solutions in Branched-Chain Paraffins, E. H. MCARDLE AND A. E. ROBERTSON, *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) p. 484-7.

Solutions of an alkyd-type resin, and of a natural and two substitute rubbers, at high concentrations in two pentanes, four hexanes, five heptanes, and two octanes show much higher absolute and relative viscosities in the branched paraffins than in the corresponding normal paraffins. An arbitrary method of predicting the viscosity of the resin solutions in branched paraffins was devised. Large differences observed between solution viscosities suggest a rough method of hydrocarbon analysis.

Chemical Compositions And Reactions

Pure Hydrocarbons from Petroleum, J. GRISWOLD, C. F. VAN BERG, AND J. E. KASCH, *Ind. & Eng. Chem.* **35** (1943) pp. 854-7.

The inadequacy of fractional distillation allowance for analysis and preparation of pure hydrocarbons from C_6 petroleum fractions was confirmed. The operation cannot resolve mixtures containing benzene, and may give misleading results on paraffins and naphthenic mixtures. A quantitative analysis for the hydrocarbons present in a narrow-boiling Mid-Continent hexane fraction (from natural gas) was obtained by nitrating the benzene and separating the aromatic-free mixture into essentially paraffinic and naphthenic portions by selective solvent extraction, then fractionating each portion in a Podbielniak Heli-Grid column. In contrast to reports on other straight-run hexane fractions, the 3-methylpentane content was too small for identification of this hydrocarbon. Methylcyclopentane is of widespread occurrence in virgin naphthas

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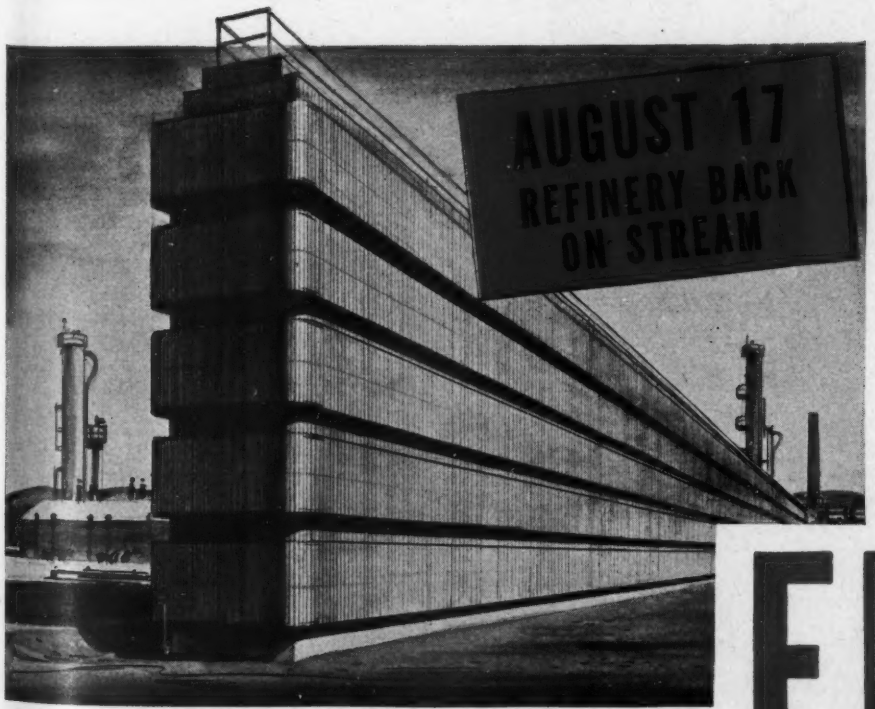

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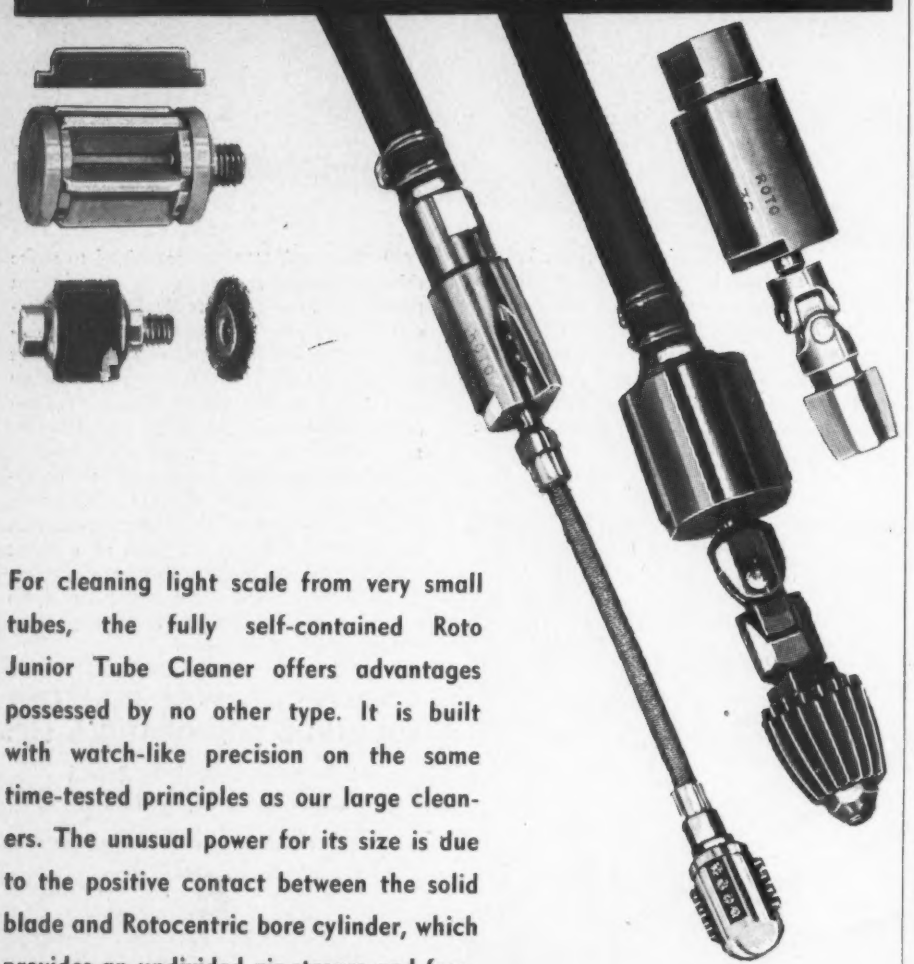

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and is more difficult to separate quantitatively from n-hexane than has been generally appreciated.

The Isomeric p-Dibutylbenzenes, G. F. HENNION AND L. A. AUSPOS, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1603-6.

The isomeric p-dibutylbenzenes have been prepared by direct alkylation of the butylbenzenes or by acylation of the butylbenzenes followed by Clemmensen reduction. The isomerization of n- and isobutyl groups to s- and t-butyl groups respectively, by boron fluoride in alkylation procedures has been reconfirmed. At temperatures up to 75° no isomerization of a butyl group already in the benzene ring is effected upon further alkylation by boron fluoride either alone or with phosphorus pentoxide. Eight new p-butylbutyrophenones were prepared and described. The physical properties of the p-dibutylbenzenes and p-butylbutyrophenones are tabulated.

Formation of Cyclopropanes from Monohalides. IV. Some Reactions of 1-Chloro-2-methyl-2-phenylpropane (Neophyl Chloride), F. C. WHITMORE, C. A. WEISGERBER AND A. C. SHABICA, JR., *Jour. Am. Chem. Soc* **65** (1943) pp. 1469-71.

Some reactions of neophyl chloride were studied. These were found to resemble the corresponding reactions of neopentyl chloride but the latter is more reactive with sodium and less reactive with ethylsodium. Both chlorides are inert to most basic reagents, with neopentyl chloride but the latter is more er activity. The relation of the Wurtz reaction to the action of a halide with an alkylsodium is further demonstrated.

A Series of a,ω-Dimercaptans, W. P. HALL AND E. E. REID, *Jour. Am. Chem. Soc.* **65** (1943) p. 1466.

The a,ω-dimercaptans up to dodecamethylene were prepared. Their properties were determined and compared with those of the corresponding glycols and dibromide. The melting points and boiling points at 10 mm., 100 mm., and 760 mm. pressure, density, refractive index, latent heat of evaporation, and content of sulfur for each of the mercaptans are tabulated. The methods of preparation used are described.

Manufacture: Processes And Plant

Chemistry and the Petroleum Industry, A. E. DUNSTAN, *Jour. Inst. Petr.* **29** (1943) pp. 163-89.

The subject of refinery technology is briefly reviewed including the distillation, cracking, destructive hydrogenation, white products, chemical and physical refining, lubricating oils, solvent extraction, synthetic lubricating oils, and the utilization of petroleum gases. In utilizing gases, most of the work has been done on the 4 carbon fractions. The production of tertiary butyl alcohol from isobutene, as well as the dimerization of isobutene is considered. Copolymerization of isobutene and n-butene is described. Another development arose when it was discovered that isobutane would smoothly unite with the butenes to yield isooctane in one operation. Isobutane will also add to ethylene to yield neohexane. Synthetic products of high molecular weight products derived from petroleum are briefly

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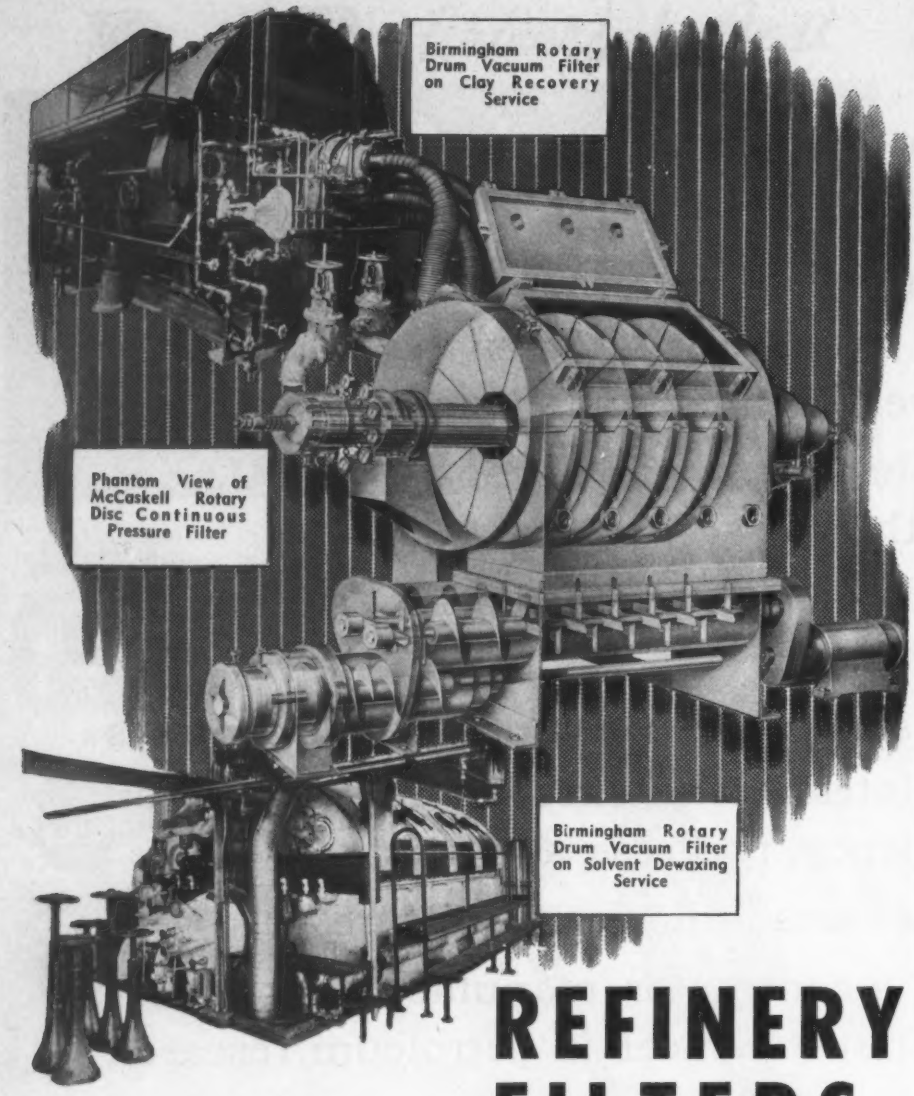
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considered, among them, synthetic rubber, polystyrenes, and dimyl polymers. The place of the chemist in the refinery industry is discussed.

Design for Hydrocarbon Absorption and Stripping, W. C. EDMISTER, *Ind. & Eng. Chem.* **35** (1943) pp. 837-9.

The recovery of valuable hydrocarbons from multi-component gaseous mixtures by absorption, followed by steam stripping of the enriched solvent, is an important process in the petroleum industry. In spite of the importance of these operations, no rapid accurate method of design has been proposed. Such a method is presented in this article. Equations are developed for making hydrocarbon absorption and stripping design calculations. Effective absorption (or stripping) factors, obtained by analytical equations from the terminal conditions, are used in the method. Absorption and stripping efficiencies are computed by equations using these effective factors and taking into account the compositions of the wet gas and the lean oil in the case of absorption and rich oil, and the stripping gas in the case of stripping. The application of the method is outlined and illustrated. For components appearing in both wet gas and lean oil it is frequently necessary to apply both the absorption and stripping equations. A comparison of this and other methods with plate-to-plate calculations indicates that this method provides an accurate and rapid short cut procedure.

Countercurrent Multitubular Heat Exchangers, M. G. LARIAN, *Ind. & Eng. Chem.* **35** (1943) pp. 840-4.

The correct method for calculating the heat transfer area of countercurrent tubular heat exchangers is by integration of $wcdt = U(T - t)dA$. The integration is graphical and requires lengthy calculations. Simpler methods are compared for accuracy and simplicity. Methods of predicting film coefficients in such cases as those used in the article are briefly discussed. The author states that for the present the important fact is that film coefficients predicted from the Dittus-Boelter equation are lower than those predicted from the Sieder-Tate correlation; yet they may be high by as much as 60 percent when compared with experimental values. It is evident that there is a great need for reexamining all available data for the purpose of recommending a correlation simple enough to be acceptable and still that compares favorably with the analytical equation. Until then it is left to the individual designer to make the choice between the Dittus-Boelter equation and the Sieder-Tate correlation, when the Reynolds number is greater than 8000. For a Reynolds number less than 8000, the use of the Dittus-Boelter equation is out of the question; therefore the Sieder-Tate graphic correlation which extends to include the transition and the viscous flow regions should be used.

Power Consumption of Propeller-Type Agitators, C. E. STOOPS AND C. L. LOVELL, *Ind. & Eng. Chem.* **35** (1943) pp. 845-50.

Mixing is an engineering operation that has probably received less quantitative study than any other operation in the process industries. Because mixing can be performed in various ways, and there are so many variables involved,

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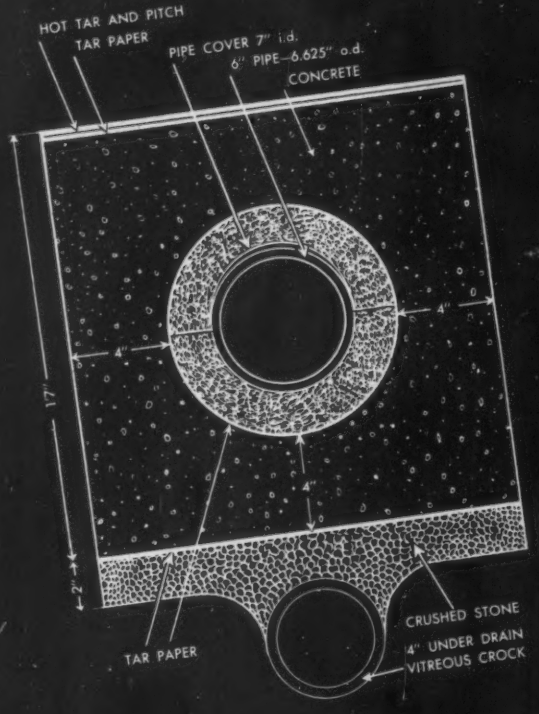

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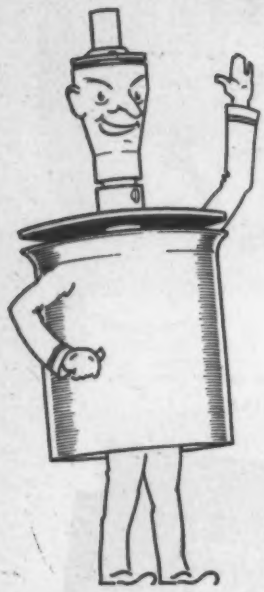

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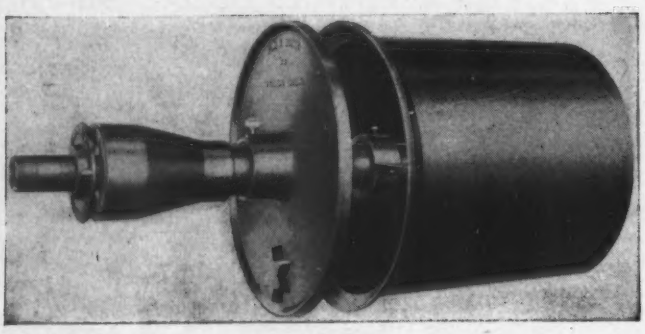

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and a rational correlation seems so difficult, most workers have sidestepped the attempt to correlate. The authors' study was concerned with only one aspect of the general problem: a study of the power necessary to turn certain propeller-type agitators under varying conditions. The dynamometer used to measure the shaft power is described. The data obtained were correlated by dimensional analysis. The following equation, in consistent units, gives the best correlation of the data: $P = 0.56_p{}^{0.8}u^{0.2}N^{2.8}L^{3.7}D^{0.9}$. Attention is called to the fact that no critical value was found for the modified Reynolds number pNL^2/u. A bibliography of nine references to previous work on the general subject is included.

New Approach to Continuous Reactor Design—II, A. Brothman, A. P. Weber and E. Z. Barish, *Chem. & Met. Engr.* **50** (1943) pp. 107-10.

This is the second of three articles dealing with a new theoretical approach to the design of continuous processing equipment for carrying out liquid-phase reactions and other combining and mixing operations. The methods described enable the engineer to design readily for a close approximation of the result that will actually be achieved by equipment so designed, and to do so with a greater degree of certainty than by earlier methods. In an earlier article the basic expression was derived that shows the retention time of each part of the effluent from a continuous liquid-phase system of one or more vessels in series. The present article combines this expression with the combining-velocity characteristics for various types of phenomena.

Fluorescent Method Detects Leaks in Process Vessels, F. Catlin, *Chem. & Met. Engr.* **50** (1943) p. 116.

A new method for the detection of leaks in vessels, fittings, castings, valves, piping and other process equipment, without the use of pressure, is available through a fluorescent penetrant which is applied to suspected spots, and is then made visible in the event of a leak by near-ultra-violet light applied to the opposite side of the surface. It is claimed that the new method can detect leaks that may be undetectable by other methods. At present the method has been found to be effective on the seams of vessels of ¼-inch sheet metal, while a lesser amount of experience with thicker plate has indicated that good results can be had up to ¾-inch plate. On still thicker plate, or on castings more than 1 inch in thickness, difficulty in using the method has been encountered since the penetrant can become trapped or lost in a cavity or too-long channel beneath the surface. Several applications of the method, as in the manufacture of aluminum aircraft gasoline tanks, are described.

Corrosion of Iron by Ammonia, H. J. McDonald and M. Feller, *Chem. & Met. Engr.* **50** (1943) p. 111.

Ammonia solutions containing more than 1 percent of ammonia completely prevent the corrosion of iron in the form of steel wool. Investigation showed that in aqua ammonia solutions ranging downward in concentration from 1 percent there is increasing susceptibility to corrosion. This tendency, however, is still relatively small at 0.1 percent con-

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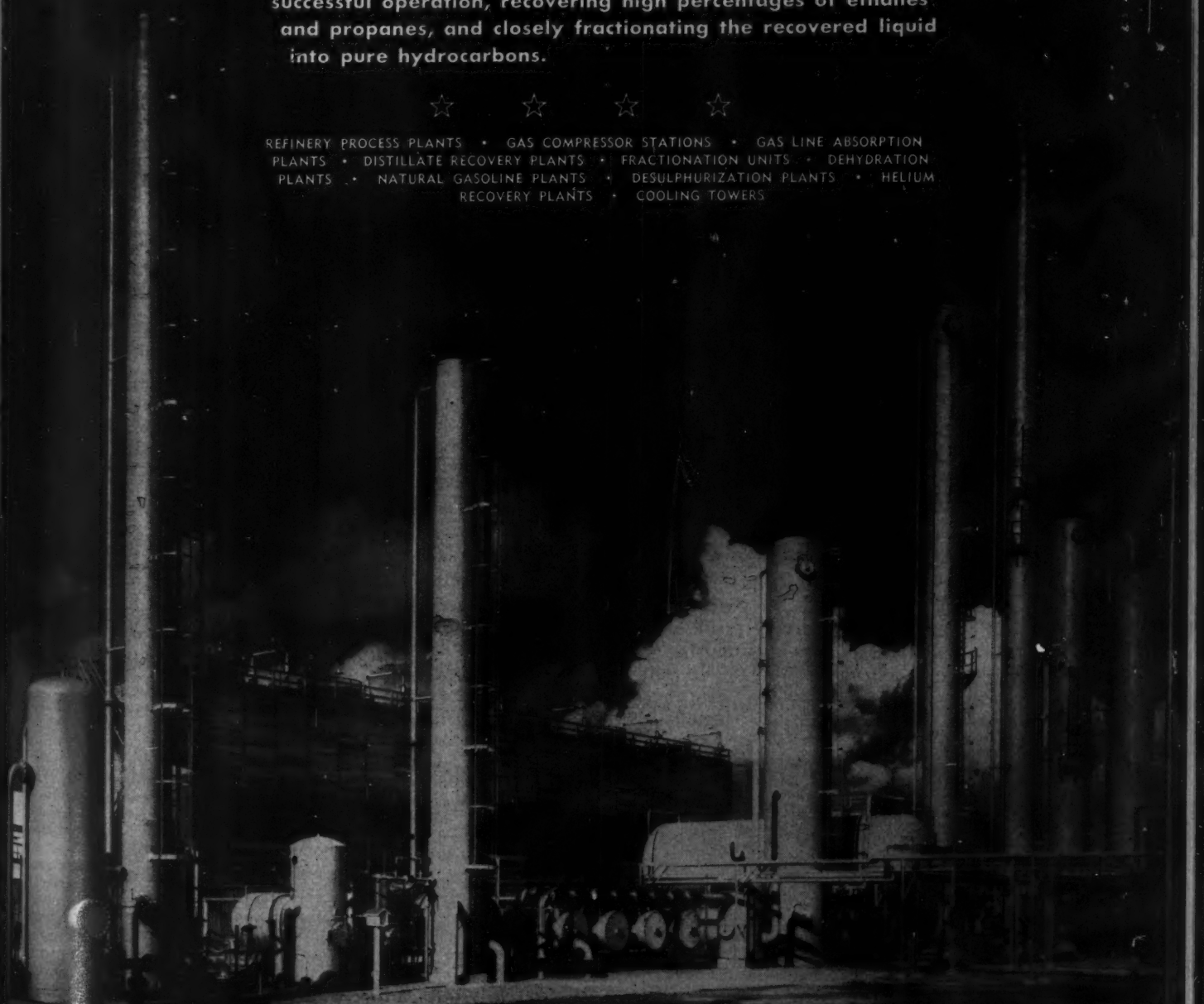

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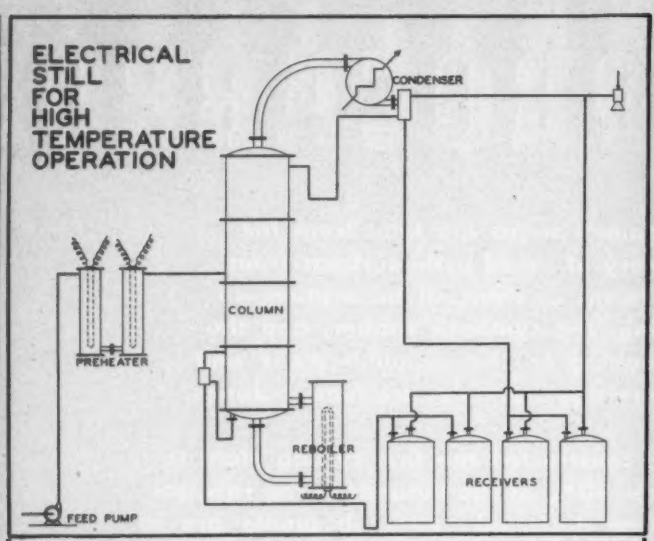

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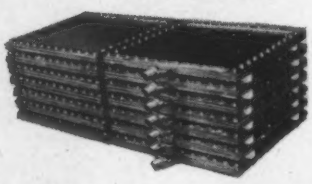

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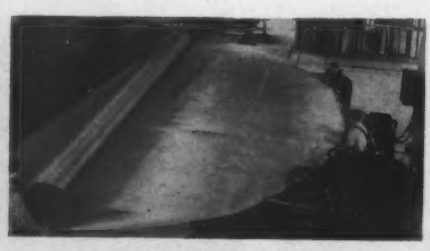

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centration. The procedure used in the experimental work is described in some detail.

Products: Properties And Utilization

Propane Instead of Acetylene, W. A. KIRKBY, *Fuel in Science & Practice* **22** (1943) p. 54.

A 56-pound cylinder of propane is equivalent to three 200-cubic foot cylinders of dissolved acetylene for metal cutting and non-ferrous welding. The comparison of calorific values alone is not a sufficient basis for comparing the two gases. Differences in flame temperature, and in the mechanism of combustion are important. Propane had a maximum flame temperature of 2760° C. as compared to 3130° C. for acetylene. This is an advantage, and permits more perfect oxidation and greater cutting speed. The author believes that there is some question as to whether propane will give as reliable welds with non-ferrous metals as acetylene because of the tendency to intense oxidation at high temperatures. The reducing zone in the envelope of the oxyacetylene flame retards the undesirable effects of atmospheric oxygen. The propane-oxygen flame is more difficult to adjust than the acetylene-oxygen flame. However, the propane flame does not strike back as easily and the speed of flame propagation is about one third that of the acetylene flame.

Industrial Alcohol for War and Postwar, Chem. & Met. Report, *Chem. & Met. Engrs.* **50** (1943) pp. 119-126.

Within the last year or so, the demand for industrial alcohol in this country has multiplied several fold over the peak of peacetime needs. Manufacture of explosives and the production of butadiene for synthetic rubber represent two of the largest of the new demands, although it is true that practically all normal industrial users have required more alcohol for their ordinary purposes because of expanded wartime activities. In prewar years the need for industrial alcohol ranged from about 110 to 140 million wine gallons per year. Major uses of industrial alcohol are given in tabular form for a several year period. Under prewar conditions over 70 percent of the domestic supply of industrial alcohol came from blackstrap molasses. The second largest source, contributing some 15 percent of the total, was synthesis from unsaturated hydrocarbons separated out of petroleum refinery gases or ethylene from other hydrocarbn cracking. Under war conditions conversion of the beverage distilleries has contributed possibly 50 percent of the total. The manufacture of alcohol from by-products of hydrocarbon gas has been carried out in the United States by Carbide and Carbon Chemicals Corporation and by the Standard Oil Company. The conventional procedure is to absorb ethylene in strong sulphuric acid and then hydrolyze the ester into ethyl alcohol. On account of the large quantity of steel required for plants of this type a program of expansion in this direction was undesirable in wartime. In spite of this it is believed this country is now producing from 50 to 60 mllion gallons annually of synthetic alcohol as compared to 35 million gallons for the fiscal year 1941. Methods for producing the alcohol from wheat, from sulphite liquor, by the hydrolysis of wood and from corn and molasses

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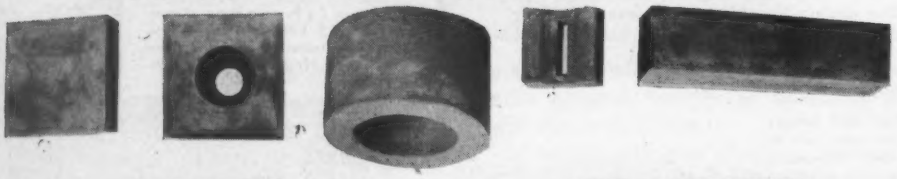

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are briefly described. The subject of postwar alcohol demands and supplies and of future processes for the production of alcohol are discussed.

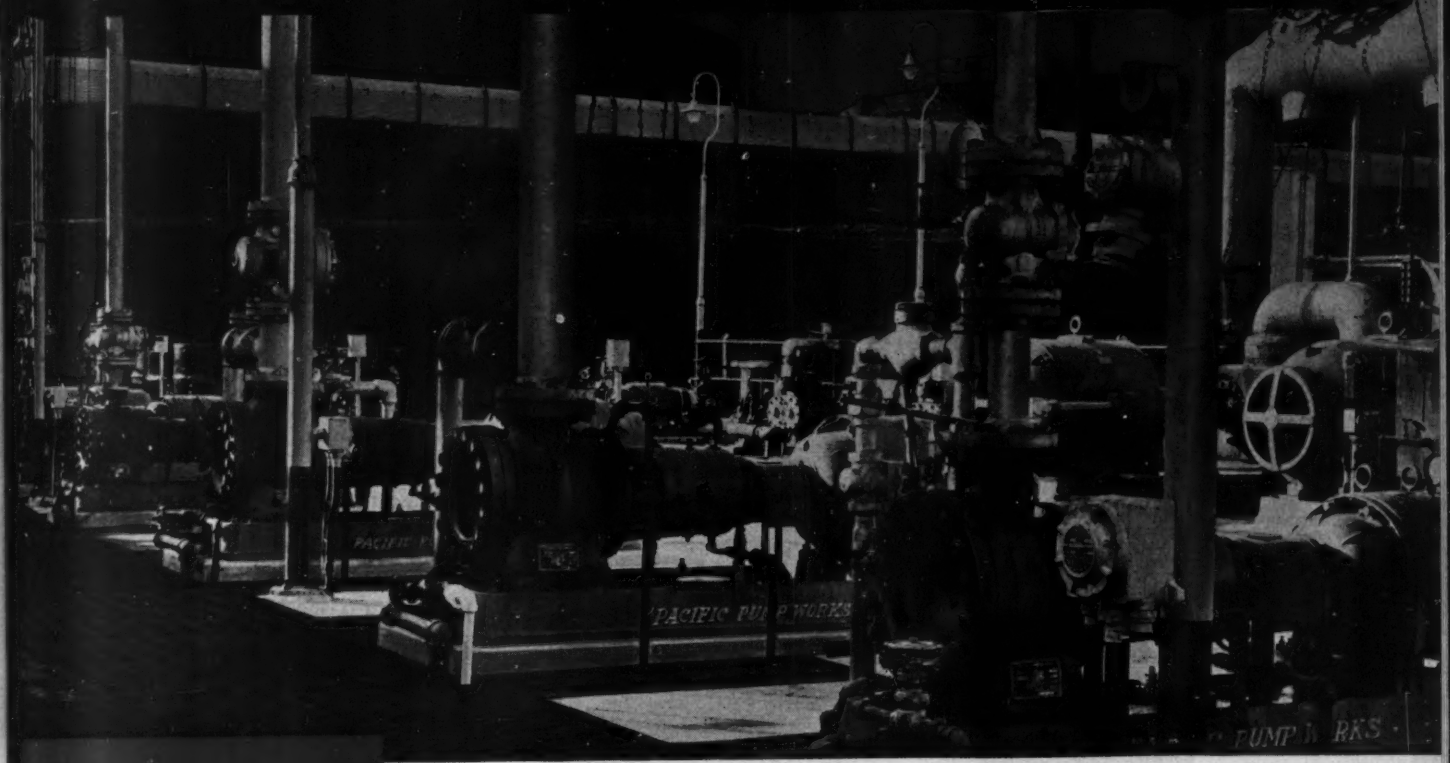
Fouling and Wear in Diesels from Fuel, G. H. CLOUD AND A. J. BLACKWOOD, *SAE Jour.* **51** (1943) p. 58.

The authors note that the high-speed diesel engine may be sensitive to differences in fuel properties. Some differences in fouling and wear cannot be explained by consideration of the lubricant used. To study the question, 40 fuels were tested in three makes of automotive diesels. The test proved that suitable fuels were necessary for automotive diesel engines if trouble from fouling and wear are to be avoided. If diesel fuels are clean and free from corrosive agents, the main properties leading to engine fouling and wear are sulfur content, ignition quality, viscosity and volatility. Sulfur content is the most important of these. An increase in sulfur from 0.2 to 1.0 percent can increase engine fouling 40 to 80 percent, and ring and cylinder wear may increase from 2-fold to 6-fold. These difficulties are probably occasioned by sulfur trioxide that attacks the lubricating oil, producing an insoluble sludge that leads to varnish and carbon formation and increased ring and cylinder wear. There is little improvement to be had in increasing the cetane number of the fuel above that necessary for smooth operation. Reducing the cetane number from 50 to 35 increased engine fouling 10 to 30 percent but did not affect wear. Fuel viscosity and fuel volatility should be specified rigidly. Increasing viscosity from 35 to 40 S.U. seconds at 100° F. caused a 30 percent increase in engine fouling. The authors note that their findings on bad effects of sulfur in diesel fuels apparently did not apply to low-speed diesels in marine or industrial service as indicated by a 12-month test on two marine diesels.

Mineral Insulating Oils, A. G. ASSAF AND J. C. BALSBAUGH, *Ind. & Eng. Chem.* **35** (1943) pp. 909-16.

The authors studied the effect on some of the non-hydrocarbon components normally found in commercially refined oils, mainly the sulfur compounds. Representative samples of thio-ether, disulfides, mercaptans, and a few special samples were studied. At the same time the effect of oxidation inhibitors on the electrical losses produced during a limited oxidation was investigated. Consequently a group of six oxidation inhibitors was added to the list of additives studied. The inhibitors did not produce high electrical losses by increasing the length of the induction period. In the continuous-oxidation tests the inhibitors that reduced oxygen consumption, in general also reduced the electrical losses. Tert-amyl phenyl phosphite produced the lowest electrical losses under the conditions of limited oxidation, presumably because of its inactivation of the copper surface. Sulfur compounds in concentrations found in refined oils may increase or decrease the electrical losses produced by a limited oxidation, depending on their type and structure. Among the samples studied, a thioether and a mercaptan produced high electrical losses during continuous oxidation. Sulfur compounds that inactivate copper surfaces produce low losses during limited oxidation. The non-hydrocarbon components of a mineral

CHECK THE PUMPS IN THE LEADING REFINERIES



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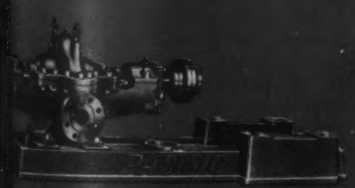

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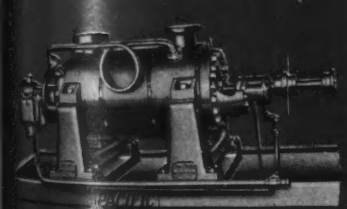

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oil determines to a large extent the characteristics of an oil under limited oxidation. In many cases a few tenths percent of one percent of added compounds can change greatly the characteristics of an oil.

Deterioration of Lubricating Oils, J. J. JACOBS AND D. F. OTHMER, *Ind. & Eng. Chem.* **35** (1943) pp. 883-89.

Lubricating oils must not only lubricate engines, but also seal piston rings, carry away carbon and soot, and cool the engine. To do this they must be stable in use. In modern high-compression engines, the natural stability of mineral lubricating oil has not been high enough to withstand the severe operating conditions. Since many of the synthetic additives developed contain critical materials, the possibility of using a natural product was investigated. Commercial soybean lecithin is an oil-soluble material containing phosphorus and nitrogen, two elements claimed to have desirable properties in additives. The optimum concentration of this cheap, readily available material was determined by the Sohio oxidation test. A comparison with other commercial additives was made using different base stocks and oils of different viscosities. Some observations of the effect of method of refining on the stability of oils were made. Phosphatides were found to be good oxidation inhibitors. The amounts of insolubles are reduced as well as the viscosity increase and the neutralization number. They are effective in oils from widely varying base stocks and in oils refined by different methods. They compare favorably with several commercially accepted inhibitors.

Lubrication Facts for Present Production, C. E. S. EDDIE, *Great Lakes Steel Corp. Ind. & Power* **44** (1943) pp. 61-3.

The lubrication of a turbine-driven pump is described as an example of the importance of selecting the right oil for a given purpose. The turbine speed of 5580 rpm was reduced to 710 rpm for the pump. The large gear ran in oil which was of such quality that it did not cling to the gear. The operating temperature of 160 to 175° F. resulted. This oil was replaced by a treated oil containing an additive to increase film strength and retentivity. The oil adhered to the gears and was not thrown off centrifugally. The operating temperature dropped to 140° F., and it was felt that the change would prolong the life of the equipment many years. The use of an extreme pressure lubricant in a screw-down assembly consisting of a worm, wheel and screw, is described, in which the replacement of previously used oil resulted in an increase in run length from 2½ to 18 months. Great Lakes Steel Corporation saves money through reclaiming its oil. Reclaimed diesel oil proved better than new oil for use in locomotives, greatly reducing diesel maintenance on liners, bearings and other wearing parts.

Determination of Tetraethyllead in Gasoline, L. SCHWARTZ *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) pp. 499-501.

The production of maximum quantities of high-octane aircraft engine fuels necessitates the use of tetraethyllead to the top limits of the permissible tetraethyllead content. To facilitate the commercial content. To facilitate the commercial blending of gasolines to these top limits,

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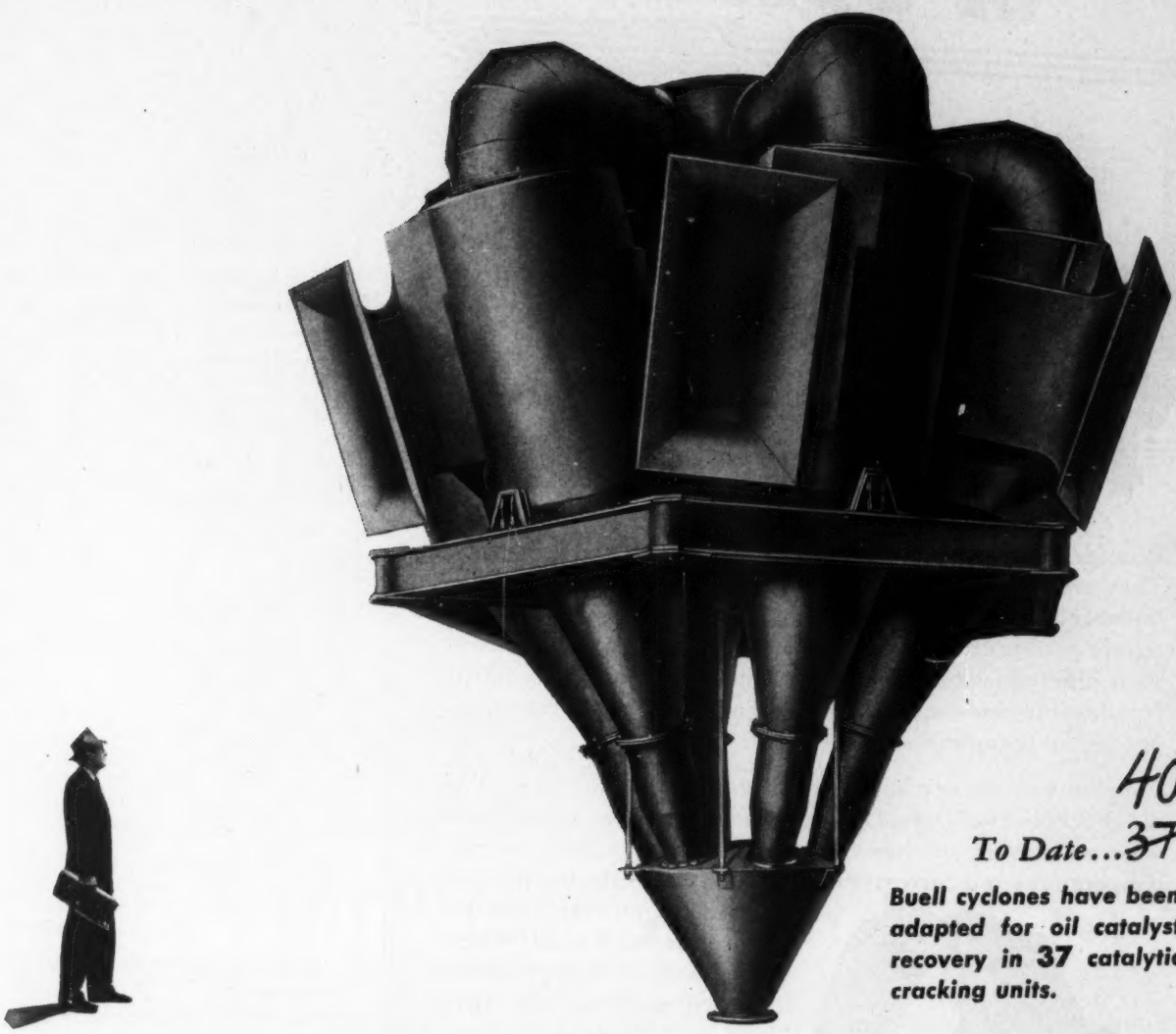

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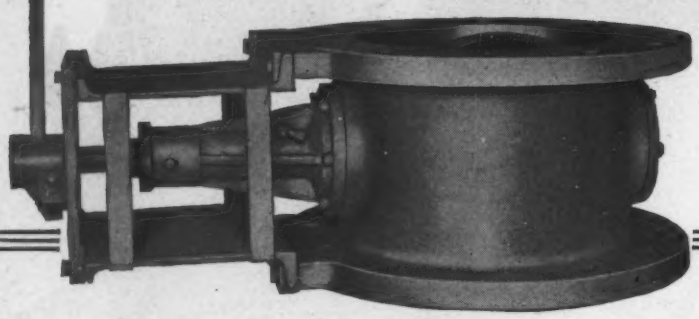

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an accurate and rapid method for the determination of tetraethyllead is required. A procedure for the rapid determination of tetraethyllead in gasoline, based on modifications of the Baldeschwieler nitric acid method is described. By using 40 percent nitric acid containing 6 percent potassium chlorate and a separatory funnel, complete extraction of the lead is effected in 8 minutes with clean-cut separations and negligible heat rise even with 100 percent cracked gasolines. The amount of lead is determined in the extractions by either volumetric or gravimetric methods. When frequent determinations are to be made, a preferred volumetric chromate method is recommended as more rapid than the gravimetric methods described. Tables are given showing typical comparative results and showing the influence of ethyl ether and acetone washings on the accuracy of the results.

Determination of Butadiene, J. F. Cuneo and R. L. Switzer, *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) pp. 508-9.

A rapid and accurate method for the analysis of 1,3-butadiene is of considerable importance in the present synthetic rubber program. Butadiene can be associated with n-butane, isobutane, isobutene, 1-butene, cis-2-butene, trans-2-butene, methylacetylene, vinylacetylene, and ethylacetylene. Any method of analysis must be accurate and rapid, regardless of the percentage of the abovementioned compounds. The authors describe a method for the determination of butadiene in gaseous hydrocarbon mixtures that are free of acetylenes. It was found possible to remove the acetylenes commonly associated with the butadiene and butenes without affecting the relative proportion of the remaining gaseous components. The determination of butadiene consists of two operations: (1) absorption of the alkenes and alkadienes in a mercuric nitrate solution; (2) hydrogenation of the alkanes and alkadienes to alkanes. From these data the mole percent of alkadienes in the hydrocarbon mixture can be calculated. The apparatus and procedure are described in detail and typical results are tabulated.

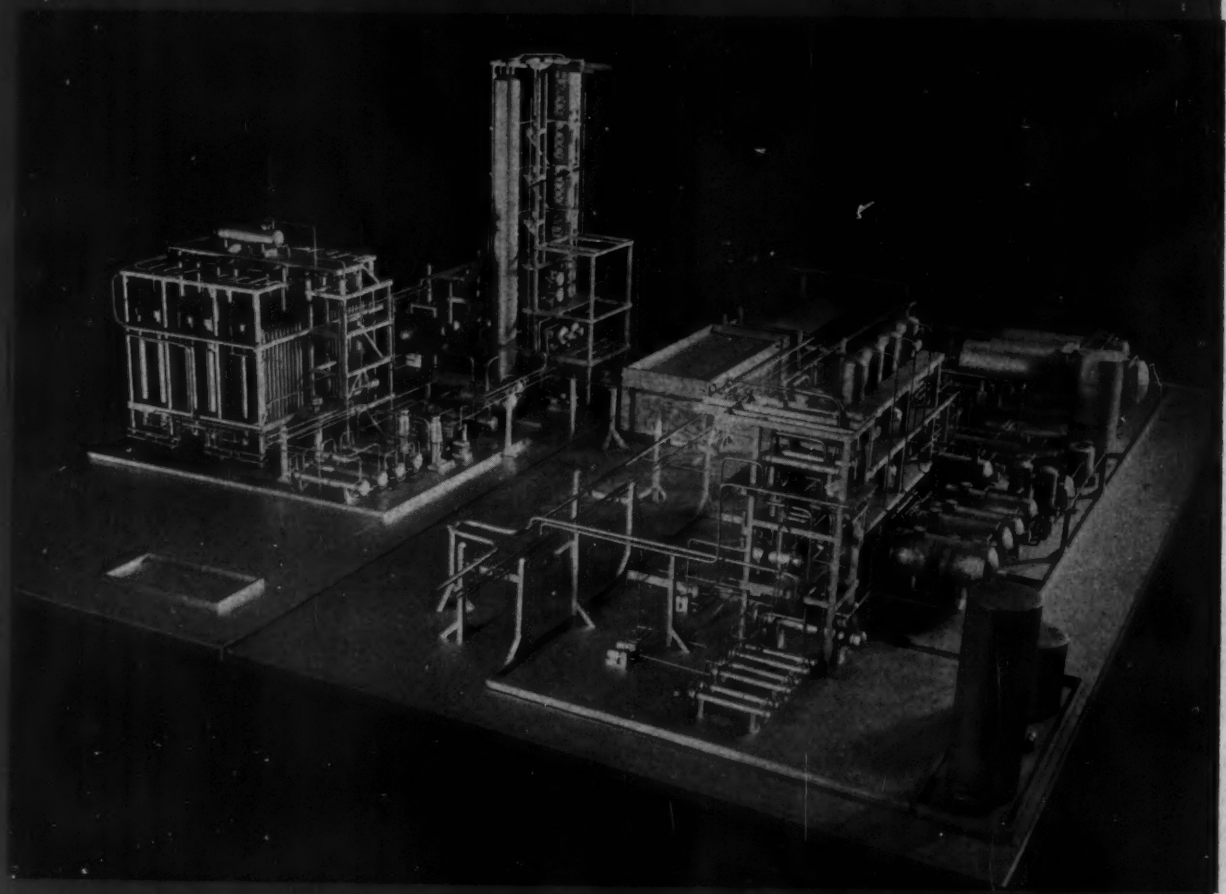
N-Methylaniline Point of Viscous Petroleum Oils, B. W. Geddes, L. Z. Wilcox, and E. H. McArdle, *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) pp. 487-9.

For testing lubricating oils of relatively high aniline point, e.g., above 80° C. a modification of the aniline point test wherein aniline is replaced with N-methylaniline, is suggested. Preliminary results indicate that the method can also serve in testing other petroleum products. At present, an important use of this type of test is in estimating the relative tendencies of these oils to attack rubberlike materials. The method of making the test is described in detail and typical results are given. Aniline points can be obtained from N-methylaniline points by adding 139° F. A.S.T.M. steam emulsion tubes offer a convenient and precise means of performing the test.

Determination of Wax in Asphalt, R. L. Betts and H. D. Wirsig, *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) pp. 478-83.

Wax can materially affect the properties of an asphalt, and the magnitude of the effect will depend upon the nature of the wax and the amount present. A re-

Model Plant TODAY...



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liable procedure capable of evaluating both the character and quantity of wax present in an asphalt is desirable. The experience of the Esso Laboratories in the determination of waxes in asphalt is described in the article. The literature of the subject is reviewed and the work undertaken to study and compare the various methods is described. The problem divided into two parts; first, the selection of a suitable solvent in which residual oils are soluble and waxes are relatively insoluble, and second, the effect of the several treating methods on waxes and on the recovery of these waxes when added to asphalt in known amounts. The Schwarz method, adsorbent method, Richardson or acid-treating method, and aluminum chloride treating methods are described in considerable detail. The aluminum chloride method has been chosen for wax determination in the Esso Laboratories. In conclusion, comment is made on two new methods that have been proposed for the determination of wax in asphalt.

Personnel Changes in Shell Organization Announced

The Shell Oil Company, New York, has announced four executive changes to meet readjustments necessitated by the recent creation of a department of industrial relations.

George H. Dempster becomes manager of the personnel department. John C. Quilty has been appointed manager of industrial relations. L. A. Lohman was named assistant manager of the newly created department. The new department functions closely with the personnel department under the combined general management of E. H. Walker.

Walker, a native of Mississippi, joined the organization 11 years ago, at the Norco refinery. He was transferred to St. Louis in 1936 as personnel assistant to the vice president in charge of manufacturing, and continued in that post until removal of the company's head office to New York in 1940, at which time he was made personnel manager.

Dempster, born in Ohio, came to Shell in 1933. For a short while he was assigned to the marketing department in the Cleveland offices before he was called to the former general offices in St. Louis where he was attached to the president's office. He went to New York in 1940.

Quilty, a graduate of the University of Oklahoma, entered Shell's legal department at Tulsa where he had been engaged in private practice. Later he was sent to the legal department in St. Louis and in 1940 was placed in charge of the company's legal department at Centralia, Illinois. He went to New York in 1942 as office assistant to the president.

Lohman's association with Shell dates from 1930. He was personnel manager at the Wood River refinery for 10 years, after which he was transferred to the head office in New York as industrial relations assistant in the personnel department.

Grease Institute to Hold Conference in Chicago

The National Lubricating Grease Institute will hold its eleventh annual meeting in Chicago from November 1-3 at the Edgewater Beach Hotel. A program has been arranged covering technical matters and subjects of immediate concern to the grease manufacturer.

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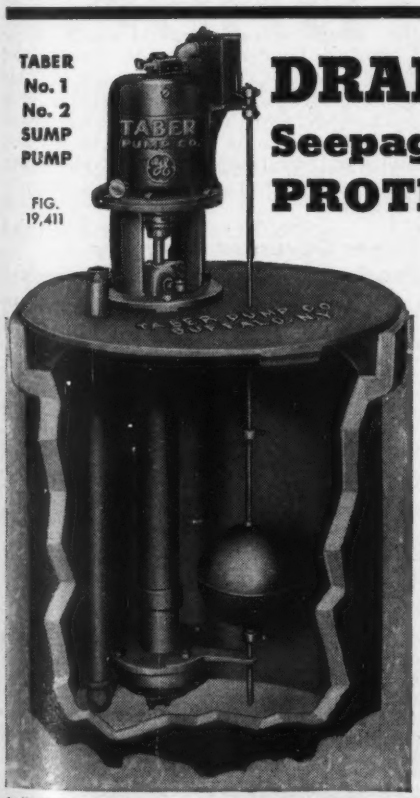
FIG. 19,411



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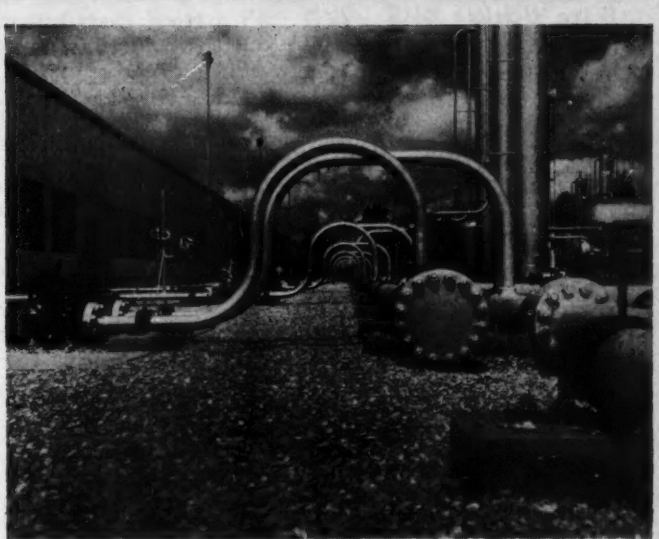

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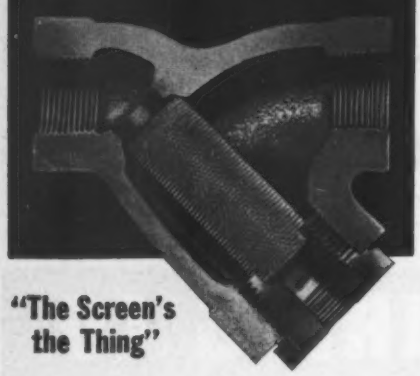

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☆ BUSINESS NOTES ☆

Lawrence B. Jackson Directs Diesel Engineering for Alco

Lawrence B. Jackson has recently been appointed director of engineering for the Diesel Division of American Locomotive Company, 30 Church Street, New York.

Jackson is a graduate of Stevens Institute of Technology. After association with American Hawaiian Steamship Company as superintending engineer, and with Texas Steamship Company as plant engineer at the Bath, Maine, shipyard and superintendent of the Technical Division, Marine Department, he became associated with Fairbanks, Morse & Company in 1925, rising to the position of manager of engineering in 1936.

He has contributed to various technical journals on subjects relating to internal combustion engines, and is the inventor of an interlock hydraulic control for water-gas manufacturing and an exhaust silencer.

He is a member of the American Society of Mechanical Engineers, the Society of Automotive Engineers, Society of Naval Architects and Marine Engineers and is a member of the Technical Committee of the American Bureau of Shipping.

New Distributors for Quigley Products in Texas and Oklahoma

Steve C. Maples & Company, 1120 South Florence Place, Tulsa, Oklahoma, and 112 Brown Street, Pampa, Texas, has been appointed distributor for Quigley Products. The company will stock refractory and insulating materials for the construction and maintenance of all types of industrial furnaces, acid-proof cements, joint sealing compounds, cleaning compounds and types of protective coatings.

Heman Greenwood Heads Foreign Department for Carrier

Heman Greenwood has been elected vice president of Carrier Corporation, in charge of its International Division and assumed his new duties October 1 in Syracuse, New York, headquarters of the company.

Greenwood graduated from the University of California with a degree in mechanical engineering. His first foreign assignment was in China as a member of the faculty of Hunan Polytechnic Institute in Chengsha. He has long been active in the Council on Foreign Relations and is a director of the American-Brazil Association. He is a member of the American Society of Mechanical Engineers and of the American Society of Civil Engineers.

E. A. Phoenix Becomes Assistant Manager of J-M Pipe Department

E. A. Phoenix has been appointed assistant manager of the Transite Asbestos Pipe Department of Johns-Manville, New York. He will serve as general assistant to C. A. McGinnis, manager of the Transite pipe department, and will specialize in field sales and educational phases of the business. In 1940, he became a member of the Johns-Manville Quarter Century Club, an honorary organization composed of those who have been with the company 25 years or more.

William J. Conley Appointed Consultant by Lincoln

William J. Conley, former chairman of the engineering department of the University of Rochester, has been appointed consulting engineer by The Lincoln Electric Company, Cleveland, Ohio. He will act as welding consultant for various industries, handling problems on mechanical and structural design utilizing welding, as well as metallurgical problems involving welding processes.

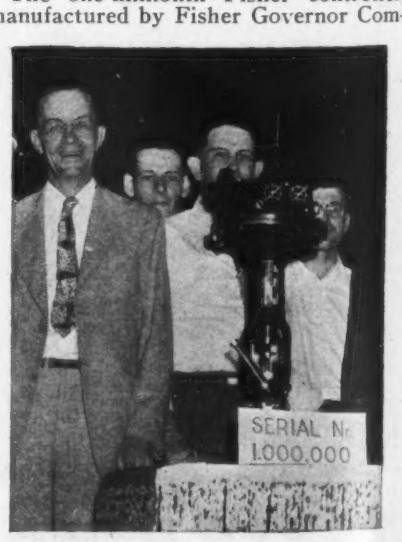
Conley is a member of the American Welding Society and American Society for Metals. He is also a member of the American Institute of Mining and Metallurgical Engineers, American Electroplaters Society, and the Society for the Promotion of Engineering Education.

Division Superintendent for Dow Company Dies in Michigan

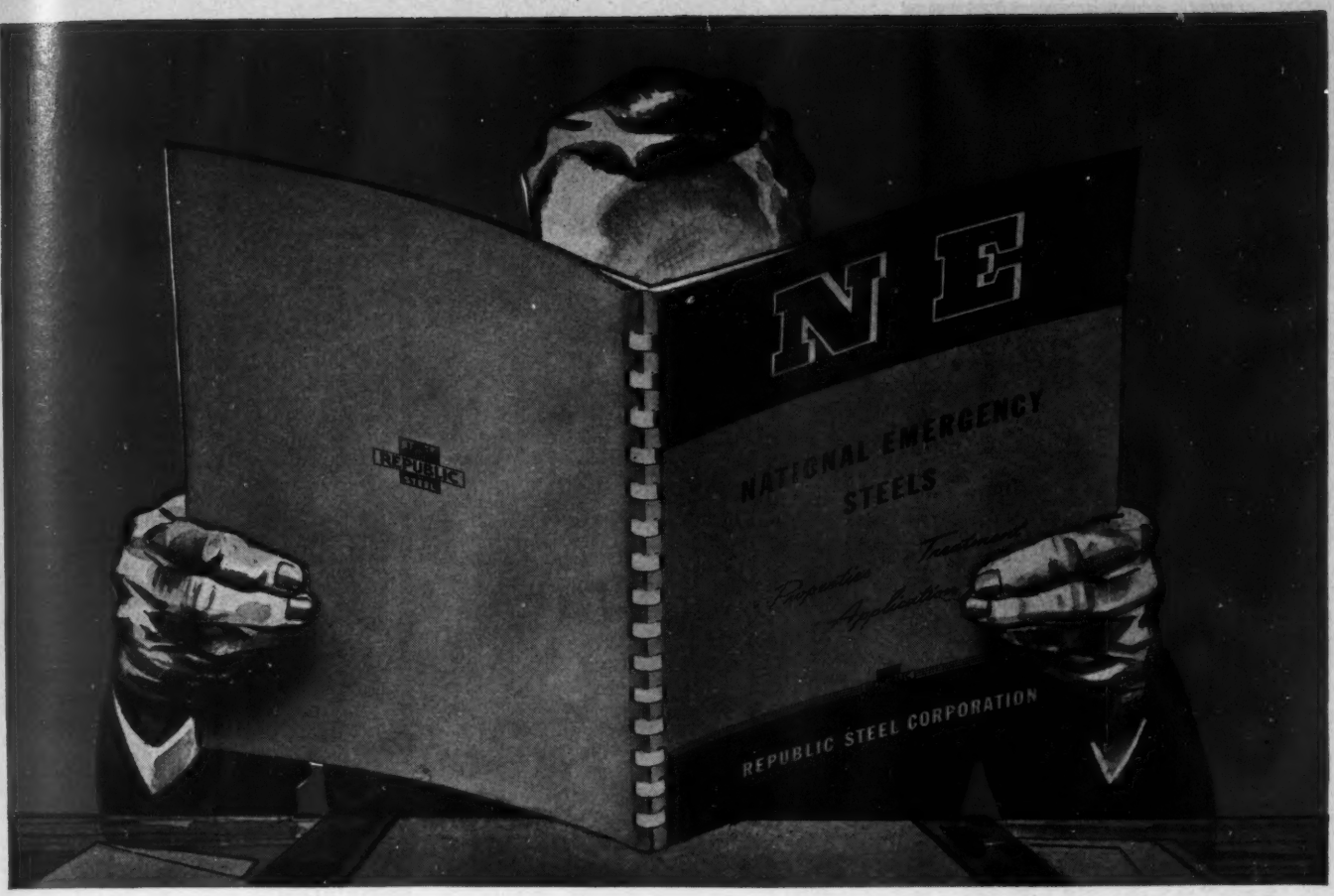
Frank W. O'Brien, widely known in the chemical world and with Dow Chemical Company for 31 years, died August 28 of a heart attack at his home in Midland, Michigan. He was graduated from the University of Michigan. At the time of his death he was divisional superintendent for the company and in charge of caustic soda production.

Fisher Governor Company Produces 1,000,000 Controllers

The one-millionth Fisher controller, manufactured by Fisher Governor Com-



N. T. Chadderon, president of Fisher Governor Company, with other workers, with the millionth controller.



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pany, Marshalltown, Iowa, was recently installed in a new aviation gasoline plant in Kentucky.

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Kallenbaugh Represents Timken Steel and Tube on Coast

S. R. Kallenbaugh has been appointed West Coast district manager of the Steel and Tube Division of Timken Roller Bearing Company, Canton, Ohio, whose Western offices are at 1526 South Olive Street, Los Angeles.

Kallenbaugh is a graduate of Mt. Union College, and has had post-graduate training in metallurgy at Ohio State University. Until his recent transfer, he was metallurgical service representative for The Timken Roller Bearing Company in Cleveland and Detroit.

Pump Engineering Service Corporation Changes Name

Pump Engineering Service Corporation, 11610 Euclid Avenue, Cleveland 6, Ohio, announces that effective October 1, the name of the company was changed to Pesco Products Company. This change has no effect on personnel or on the company's affiliation with Borg-Warner, the parent company.

National Radiator Company Names New District Manager

Paul J. Thompson has been announced as the new manager of the Philadelphia branch of the National Radiator Company, Johnstown, Pennsylvania. He has been with the company since 1936 and succeeds Harry N. Booth, who died recently.

International Nickel Company Names Department Heads

T. H. Wickenden has been appointed manager of the development and research division of The International Nickel Company, and H. J. French has been appointed assistant manager.

Wickenden succeeds the late Albion J. Wadhams. He is well known in engineering circles in the automotive industry, having been in charge of engineering at Studebaker's South Bend plant from 1913 to 1920. He joined The International Nickel Company in 1922 when he was placed in charge of developments in the automobile field for the development and research department at New York. Numerous inventions connected with the use of nickel in cast iron are credited to him, and his papers and engineering data sheet on the use of nickel in steel and cast iron have been widely published in trade journals. He is a member of the Society of Automotive Engineers, American Society for Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, and American Society for Metals. He served as a member of the iron alloys committee of the Engineering Foundation which has published the Alloys of Iron Research Monograph Series.

French is temporarily serving in the Steel Division of the War Production Board in Washington. He has been in charge of alloy steel development in The International Nickel Company's development and research division. He is president of the American Society

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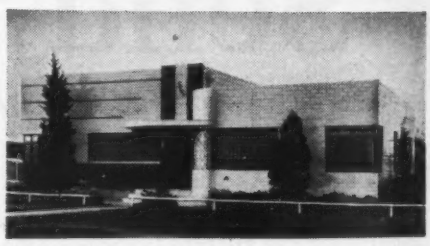

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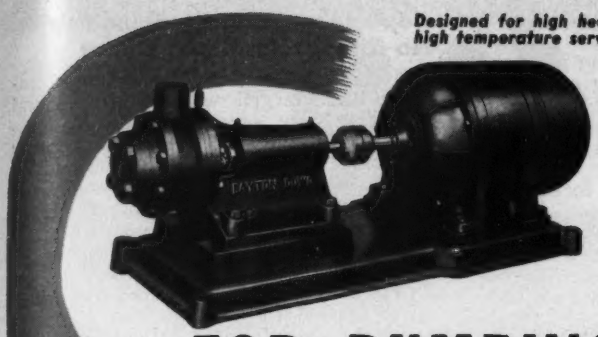

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for Metals, and has membership in the American Iron and Steel Institute, American Society for Testing Materials, and the Institute of Mining and Metallurgical Engineers. He received the Henry Marion Howe medal of the American Society for steel treating in 1931, and in 1933 was the Edward de Mille Campbell memorial lecturer for the American Society for Metals. French was honored in 1940 for his contributions to the development and advancement of welding, having been co-author of the 1940 Lincoln Gold Medal award paper, "Weld Hardening of Carbon and Alloy Steels."

Monsanto Chemical Company Announces Personnel Changes

Monsanto Chemical Company has announced the following changes in the organization, all effective November 1:

William M. Rand, vice president of the company and general manager of the Merrimac Division with headquarters at Everett, Massachusetts, was elected to the executive committee of the company, with headquarters at St. Louis.

Daniel S. Dinsmoor, assistant general manager of the organic chemicals division with headquarters at St. Louis, has been elected a vice president and will succeed Rand as general manager of the Merrimac Division.

Julius A. Berninghaus, general manager of the organic chemicals division, with headquarters at St. Louis, will retire on November 1, 1943, at age 65, a compulsory requirement under the company's retirement pension plan. He will continue his active participation in the company's business, however, in an advisory capacity to his successor.

Osborne Bezanson, vice president of the company and general manager of the Texas Division, with headquarters at Texas City, will succeed Berninghaus as general manager of the organic chemicals division with headquarters at St. Louis.

The Texas Division of the company with plants at Karnack and Texas City, will be consolidated with and become a part of the organic chemicals division.

MERIT AWARDS

Awards of merit have been made by the government to the following companies:

Le Roil Company, Milwaukee, Wisconsin, Army-Navy "E" for meritorious production of war equipment.

Edward Valve & Manfuacturing Company, East Chicago, Indiana, an additional gold star for continued production achievement, to be added to the Maritime "M" pennant which was awarded in February.

Buffalo Pumps, Inc., Buffalo, New York, renewal of the Army-Navy "E" for an additional six-month period, ending the second star to the pennant, a signal honor indicating continued splendid production of war equipment.

The Pfaudler Company, Elyria Division, Elyria, Ohio, Army-Navy "E" award for high achievement in the production of materials needed for the war effort.

Brown Instrument Company Division of Minneapolis-Honeywell Regulator Company, Philadelphia, Pennsylvania, Army-Navy "E" for outstanding production of war material.

Hope Companies Combined With No Change in Management

Hope Construction & Refining Company has merged with Hope Natural Gas Company, recently. This is a step in the simplification of the corporate structure of the two companies, which have always been affiliated, and is in accordance with a plan submitted to the Securities and Exchange Commission.

All orders for Hopane, cutting gas equipment, propane, butane, and mixtures thereof will be accepted and sales made by Hope Natural Gas Company, Clarksburg, West Virginia.

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Engineering graduate with practical refinery experience. Knowledge of planning and scheduling maintenance work, knowledge of refinery materials, some experience in time study and job analysis. Location Middle West. Reply Box 46, c/o Petroleum Refiner, Houston, Texas.

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With practical operating and mechanical experience as well as sufficient engineering training to handle cracking plant and general equipment inspection. Medium size refinery and new Aviation Gasoline Plant. Location Middle West. Reply Box 58, c/o Petroleum Refiner, Houston, Texas.

AUTOMOTIVE ENGINEER — College graduate with experience in lubrication. For Technical Sales and development work. Please include full details. Reply Box 78, c/o Petroleum Refiner, Houston, Texas.